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Airborne Tactical Displays

by

Hilton L. Conner, Jr.

March 1979

Thesis Advisor: Douglas E. Neil

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APPLICATION OF COLOR-CODING IN AIRBORNE TACTICAL DISPLAYS

by

Hilton L. Conner, Jr.
Lieutenant, United States Navy
B.S., University of Kansas, 1972

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis analyzes the operational environment and task variables of the Tactical Coordinator in the S-3A for possible application of color coding in the display symbology in the multi-purpose display. Beginning with the ASW threat to the carrier force under the CV concept, the missions of the S-3A are presented. The roles, tasks and functions of the Tactical Coordinator are identified and form the basis for an analysis of the need of color in airborne displays. Current display design requirements and discrepancies in the S-3A are discussed as a basis for areas of color application. Color research recently conducted is reviewed with the results directed toward the symbology currently used in airborne displays.

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LIST OF ACRONYMS

ADP	Acoustic Data Processor
ARU	Auxilliary Read-Out Unit
DGU	Display Generator Unit
ESM	Electronic Support Measures
FDI	Functional Description Inventory
FLIR	Forward Looking Infrared
GPDC	General Purpose Digital Computer
INCOS	Integrated Control System
MAD	Magnetic Anamoly Detector
MPD	Multi-Purpose Display
RR	Raw Radar
SC	Scan Convertor
SENSO	Sensor Operator
TACCO	Tactical Coordinator

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I. INTRODUCTION

This thesis will approach the question of the applicability of color-coding in an airborne tactical display system. The weapon system to be considered will be the S-3A built by Lockheed Aircraft Corporation for the U.S. Navy. To provide some background for those unfamiliar with antisubmarine warfare, Appendix A gives a brief picture of the current threat to the U.S. Navy and the missions of the S-3A in answer to the threat. The information presented is not meant to be an inclusive analysis of the threat or an indepth analysis of the missions of the S-3A. It is provided strictly as background for familiarization purposes. Appendix A provides a brief introduction to the S-3A weapon system and crew configuration. The reader who is familiar with the current submarine threat and the role of the S-3A may desire to disregard Appendix A.

The objectives of this thesis are to investigate current human engineering display deficiencies in the S-3A and the possibility of color-coding in display symbology as a means of illuminating some of the deficiencies. Emphasis is placed on the position of the tactical coordinator as this position is exposed to all of the information presently available in the display system. In addition, from a human factors viewpoint, the position of the tactical coordinator is best suited for discussion of color-coding in tactical displays because of the

vast amount of information provided and the uniqueness of the thought processes required by a tactical coordinator for successful completion of his job.

Some emphasis is placed on the displays used for search and detection (e.g., acoustics and raw radar). However, available literature indicates the need for additional research and hardware development before any indepth analysis of the use of color in this manner can be undertaken.

A task analysis for the tactical coordinator was conducted from an operator's viewpoint and is contained in Appendix B. This is meant to provide an insight to the specific areas where color-coding may be applied. It is not meant to supercede or contradict any previous task analysis completed on the tactical coordinator but, hopefully, will provide a different "outlook." A functional description inventory method of field testing the human factors of aircraft man-machine systems was used by NAVAIRTESTCEN, Patuxent River to analyze the operational functions of crew members in the S-3A. The results of the field tests are presented to indicate the most critical role(s) of the tactical coordinator.

A number of individuals and institutions are currently examining the feasibility of color-coding in a tactical display system from a human factors aspect. Recommendations and conclusions reached by a number of research projects provide some basis for indicating which tasks color-coding should be used for, the maximum number of different colors that should be used

in a display, and specifically, which colors should or should not be used in a tactical display.

Research indicates that color-coding is best suited for a search and detection type task. Throughout the thesis the reader should keep this in mind as the current display deficiencies and the roles and tasks of the S-3A tactical coordinator are discussed. Alteration of the current multi-purpose display system in the S-3A should benefit the crew members in those roles that are currently considered to be the most important in achieving maximum effectiveness from the S-3A weapon system and also reduce the number of current deficiencies in the display system.

It is imperative that the reader have some knowledge of the symbology and associated information provided with each symbol currently used in the S-3A tactical display system. Appendix C contains the symbology and a brief explanation of the associated alphanumerics displayed with each symbol [1]. The information provided by each symbol should be reviewed before trying to establish a need for color in that particular symbol. The symbology is used in the tactical plot display; therefore the reader should keep the symbology and the meaning of each in mind while reviewing the TACCO's role in the mission scenario that follows. It is also important that the symbology be understood while reading the chapter on color-coding.

Throughout the thesis the reader should keep in mind the following questions:

1. Could color-coding aid the tactical coordinator in his tasks?

2. Would color be beneficial in acoustic analysis or raw radar presentations?

3. Would color imagery enhance the FLIR display?

4. Could the introduction of color into the display system possibly reduce the current effectiveness of the information display?

The technological aspects of introducing color into the display hardware of the S-3A are not covered in the thesis, although certain questions arise at the end concerning possible hardware alterations. Recommendations for the use of color in S-3A multi-purpose display system are provided in Chapter VI along with a suggestion for testing the effectiveness of the system with color-coding adapted.

To establish an operational "frame of mind", a short mission scenario is provided. Hopefully, the scenario will develop some insight into the tactical coordinator thought process as he uses the information provided on the tactical display to accomplish the assigned mission.

II. ASW MISSION

To provide some background for those unfamiliar with the role of the S-3A in a tactical environment, the following scenario is discussed. This scenario is a summary of a scenario contained in Ref. 2 and is supplemented by the personal experience of an S-3A Mission Commander.

A. MISSION SCENARIO

An S-3A is tasked with laying a passive sonobuoy field in advance of a high value unit at sea. Preparation for the flight commences at least two hours prior to launch time. The preparations include reviewing the latest intelligence information on the contacts that could be encountered, establishing tactics to be used and reviewing local doctrine on the applicability of the proposed tactics. After ensuring the aircraft is capable of successfully completing the mission, the crew "man" the aircraft and re-confirm the readiness for launch. According to procedures established for either land-based or carrier-based operations, the launch is completed.

While intransit to station, the TACCO constructs a sonobuoy pattern based upon pre-flight planning. The pattern is placed in desired orientation on the MPD and fly-to-points (FTP) are inserted at designated sonobuoy drop points in the desired order to lay the pattern. As the aircraft approaches each drop point (16 in total for this scenario), the TACCO selects a

sonobuoy for drop, and the drop is made either manually or automatically as the closest point of approach (CPA) is reached. Upon completion of the sonobuoy drops, a monitor pattern for the sonobuoy field is designated using fly-to-points or surface contacts are investigated while the field is monitored. During the evolution of laying the sonobuoy field, the non-acoustic sensors are continuously monitored and all contacts are analyzed and classified as hostile, friendly or unknown. The TACCO maintains an accurate tactical plot of these contacts (especially those in close proximity of the sonobuoy field) in order to determine the influence of these contacts on the success of the SENSO in his analysis mission.

The tactical plot is maintained by the TACCO and reported on the data link net as briefed. For the purpose of the scenario, a contact is gained on buoy number 16 and the SENSO classifies the contact as a hostile submarine. The TACCO analyzes the tactical situation and selects a tactic to deploy four passive directional sonobuoys, numbers 17, 18, 19 and 20. The contacts on the tactical plot are analyzed for influence on the hostile contact information and for influence on the proposed tactic. The sequence of events from launch to this point in time are depicted in the sonobuoy pattern in Fig. 1.

The TACCO establishes four fly-to-points in the system and directs the pilot to make a high speed let-down to the first sonobuoy drop point (buoy 17). The localization phase now commences. Upon completion of the last drop (buoy 20),

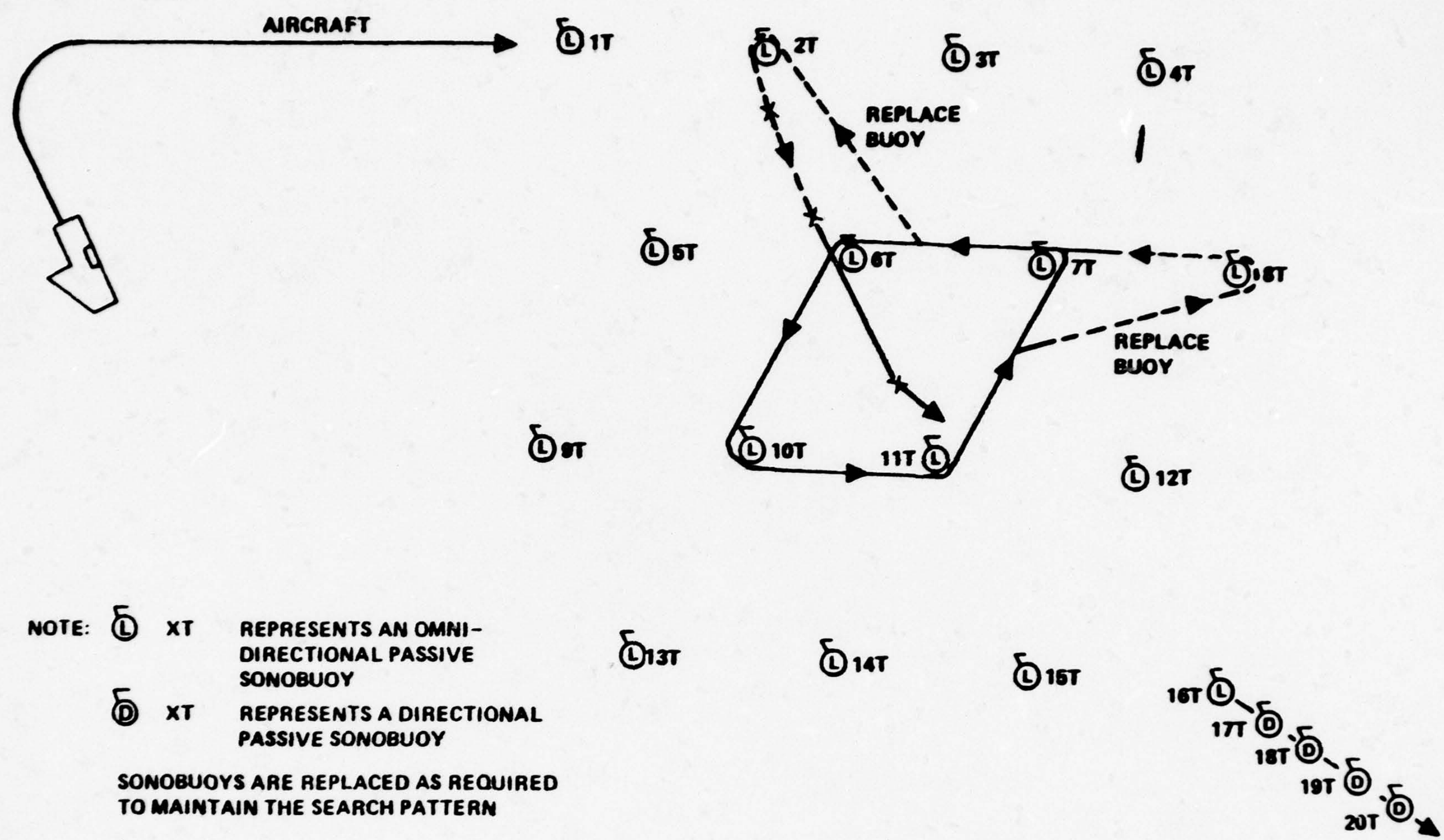


Figure 1

Typical Sonobuoy Pattern

the TACCO orders a parallel return to the vicinity of buoy 19. The SENSO gains contact on buoys 18 and 19, verifies that the contacts are the same target, and passes the bearing information to the TACCO MPD. Buoys 18 and 19 together with four successive bearing line fixes are shown in Fig. 2. Generally in such a localization phase, additional sonobuoys would be dropped, giving additional fix information for increased accuracy of probable submarine location. In addition, the tactical plot presentation is studied closely to determine the influence of surface contacts on the accuracy of the bearing lines. With a multiplicity of bearing lines and sonobuoys, each identified with a time of bearing determination, the latest information is generally considered to be the most credible provided it is not severely influenced by a non-interest contact close to the sonobuoys. The letter "D" and the dash line on the bearing lines indicate the bearing line direction of movement. This information from two bearing lines as in Fig. 2 indicate target movement to the upper right corner of the display.
Based upon mission requirements, the TACCO can now commence the tracking phase with passive sonobuoys or change to active sonobuoy employment in preparation for the attack phase. Active sonobuoy tactics will alert the hostile submarine and evasive tactics by the submarine can be expected. The tempo of operations in the airplane can be expected to increase rapidly as analysis of the submarine's tactics is required to maintain contact on the submarine. A fully evasive submarine requires

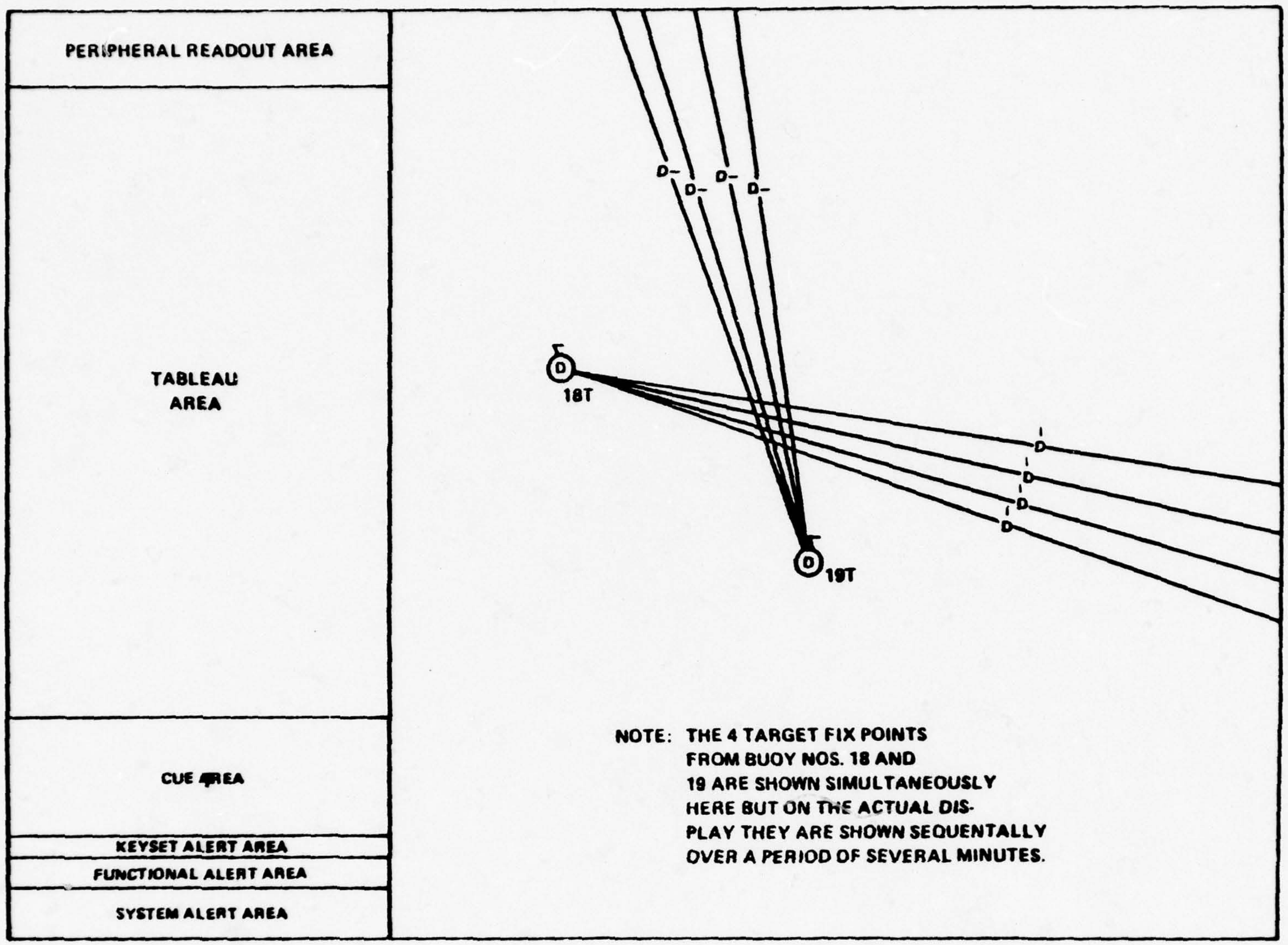


Figure 2

Two Sonobuoys with Contact on a Threat

maximum coordination within the flight crew to execute tactics quickly, formulate tactics that may be required and maintain the vast amount of communications required during a tactical evolution such as this. Obviously, it is impossible to reproduce the mental processes conducted by the crew-members and difficult to relay the man-computer coordination required with the aid of the displays and the integrated controls during tactical evolutions. This scenario should provide some insight into the sequence of events throughout a mission.

B. HUMAN PERFORMANCE

Theories of human performance suggest that there are two types of memory storage [3]. One type, called short-term memory, deals with events that have just recently occurred -- within seconds or minutes. Air traffic controllers who quickly store or retrieve information about aircraft in a traffic pattern, or battle staff analysts using rapidly updated displays to estimate characteristics of an order of battle, rely on short-term memory.

The second type of memory is called long-term memory. It involves the integration and recall of information acquired over longer periods of experience, practice and training. This is typical of the storage and recall of emergency procedures, routes or operational plans. While a clear functional or psychological distinction between short-term and long-term memory is not presently possible, there are differences in behavior that substantiate their existence.

Long-term memory has many implications for training and for training-equipment design. For example, how should one present information for relatively permanent storage and precise recall later? Short-term memory, on the other hand, is involved in receiving transitory inputs from an operating system, temporarily storing the information and almost immediately recalling it in order to control equipment or to make operational decisions.

The data processing system in the S-3A is designed to automatically process and store most of the information normally catagorized for short-term memory storage. Information such as digital data concerning bearing lines, sonobuoy specifics and contacts on the tactical plot is automatically stored and available for recall with the push of a button on the INCOS.

To facilitate accurate tactical decisions during an airborne ASW mission the TACCO is required to draw on information catagorized for both long- and short-term memory storage that is beyond the capabilities of the GPDC storage. An example of this would be tactics of an enemy submarine. To formulate tactics, the TACCO must rely on an accumulation of past information, the current situation and strategies formed during prior experiences.

III. TACTICAL COORDINATOR

A. RESPONSIBILITIES

The specific responsibilities of the TACCO are listed in Ref. 4. Based on these responsibilities, a detailed task analysis of the TACCO is presented in Appendix B. The task analysis was accomplished following guidelines established in current human engineering guides [5]. Briefly, the TACCO is responsible for tactics, coordination (internal and external), data processing system management, sensor systems management and weapon systems management. The TACCO oversees the entire tactical mission. Throughout the mission he is continuously involved in complex thought and decision-making processes based on tactical information presented to him by the MPD. The TACCO formulates strategic and tactical methodology within established doctrine to accomplish the ASW mission objective. He is responsible for the coordinated plan of action for the S-3A crew and for any support units assigned to assist the S-3A in a tactical situation.

The TACCO is not normally required to identify signals or targets in the presence of noise. These functions are assigned to the co-pilot as non-acoustic sensor operator and the SENSO as acoustic operator. The TACCO station provides display and control functions for the following non-acoustic sensor systems; radar, ECM, FLIR and MAD. The station also provides INCOS

functions and display capabilities allowing the TACCO to display and analyze passive acoustic data independently of the SENSO. During active acoustic operations only the SENSO possesses full acoustic control capabilities. The TACCO INCOS does provide a back-up capability for active and passive acoustic operations, without an auxiliary read-out unit (ARU), in case of SENSO station equipment failure. With the integrated display and control configuration, the TACCO can assign operating responsibilities, monitor operation or operate the systems himself.

B. FUNCTIONAL DESCRIPTION INVENTORY

A method initially developed by the Naval Aerospace Medical Research Laboratory's Psychology Department has been adapted to assist in field testing the human factors aspects of aircraft man-machine systems [7]. The method is known as the Functional Description Inventory (FDI) and requires a series of investigations analyzing the operational functions of crew members. The method as tested consists of a series of investigations analyzing the operational functions of each S-3A crew member, with an essential part involving the determination of roles, duties and tasks performed by each crew member. Crew members' judgments were compiled on how important these roles, duties and tasks are for mission success, how frequently they are performed on a typical mission, how adequate the training has been to ensure effective performance of the task and,

finally, how effective the system is in accomplishing these operational functions. The method adds new perspective to man-machine interface evaluations that is usually not available through the traditional evaluation of human engineering design deficiencies [8].

For the purpose of the analysis conducted, the following definitions are given:

1. Role -- a broad category of activity performed by the S-3A crew member. Each role may encompass a number of duties and tasks. Five roles were identified for each S-3A crew position. These roles encompassed 100-percent of the responsibilities of the S-3A crew members within an operational mission framework.

2. Duty -- a large segment of activity performed by an S-3A crew member. All of the duties under a role in combination define 100-percent of the role.

3. Task -- a unit of work activity which forms a significant part of a duty. All the tasks under a duty in combination define 100-percent of the duty.

Using these definitions, five roles, 18 duties and 286 tasks are proposed for the TACCO FDI [7]. The five roles and relative percentage of time and effort spent in each role are presented in graphic form in Fig. 3. The percentage of time and effort of a total mission that was spent on each role was determined by analyzing the frequency of performance role ratings in the FDI. The TACCO's duties were rank ordered by a percentile value of composite score of criticality and frequency. This ranking is

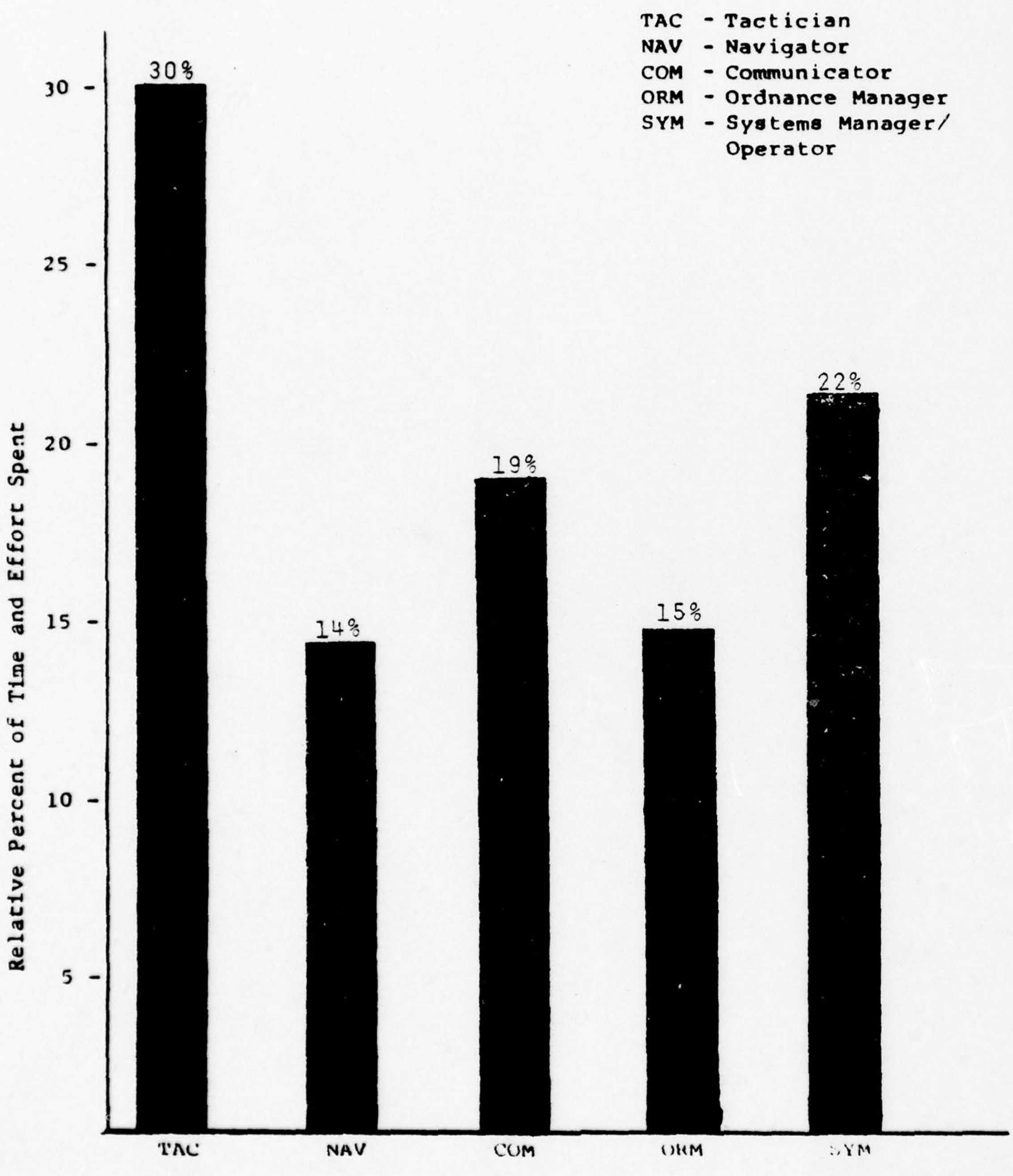


Figure 3
Relative Subsystem Area Demands (S-3A TACCO) as Indicated by Frequency of Performance Estimates of Operational Roles

provided in Table I. Criticality indicates the relative importance of each duty while frequency reflects the relative proportion of time for a duty. The composite score of criticality and frequency indicate the relative "importance" of the duty. Based on these definitions, the roles of the TACCO rank-ordered for mean system effectiveness relative to the S-3A were:

1. Tactician
2. Systems Manager/Operator
3. Ordnance Manager
4. Communicator
5. Navigator

TABLE I

TACCO Roles Rank Ordered by Relative Percent of Combined Mean Criticality and Frequency Values

Rank	Role	Criticality of Activity Mean sd	Frequency of Performance Mean sd	Relative Percent
1	Tactician	5.00 0.00	4.80 0.45	29.0
2	Ordnance Manager	4.00 0.71	3.00 1.40	21.0
3	Systems Manager/ Operator	3.00 1.82	3.40 1.52	19.0
4	Communicator	2.50 0.58	2.40 1.34	17.0
5	Navigator	2.60 0.55	2.20 0.84	14.0

IV. DESIGN DEFICIENCIES

A. TEST AND EVALUATION

The S-3A aircraft is typical of systems that are developed and evaluated by the Naval Air Systems Command (NAVAIRSYSCOM) under the Navy's departmental organizational structure. To conduct the evaluation process, NAVAIRSYSCOM has two test centers -- the Naval Air Test Center (NAVAIRTESTCEN), Patuxent River, Maryland, which is charged with the overall weapon system test and evaluation coordination and the Pacific Missile Test Center (PACMISTESTCEN), Point Mugu, California, which is responsible for missile test and evaluation. In addition to testing systems for NAVAIRSYSCOM, NAVAIRTESTCEN conducts systems tests for the Board of Inspection and Survey (BIS) with the exception of those concerned with airborne missile and missile control which are done by PACMISTESTCEN. It is the responsibility of BIS to ensure that the ships and aircraft procured by NAVAIRSYSCOM meet specification requirements and are suitable for Navy use.

B. DEFICIENCY CLASSIFICATION

During test and evaluation of a system, engineering deficiencies noted relative to a particular aircraft result in a final report that combines specifically noted engineering deficiencies and system, sub-system performance summaries. In order to catalogue various types of human engineering design deficiencies, the critical incident technique developed by Flannagen was used

by NAVAIRTESTCEN for the S-3A controls and displays [8]. For the purposes of evaluating the S-3A, human engineering design deficiency is defined as any inadequecy in a system component which impacted directly or indirectly on operator performance. The following general definitions of the various human engineering deficiencies were adopted for use in classifying deficiencies:

1. Erroneous: Presence of inappropriate equipment and job aids.
2. Ill-placed: Out of position for efficient system operation, hazardous position or blocking other functions.
3. Inaccessible: Unable to be reached or difficult to operate due to position.
4. Inconsistent: Lack of uniformity in displays, controls and use of color-coding.
5. Incompatible: Inadequate for performing intended operation; e.g., ill-designed or damaged equipment.
6. Missing: Absence of or need for display or equipment.
7. Too Complex: (a) Defined procedures too detailed or ambiguous. (b) Multiple displays and controls combined without regard for functional arrangement.
8. Unclear: Ill-defined procedures and displays.
9. Unneeded: Unnecessary displays, equipment or controls.
10. Unreadable: Legends, displays or instructions not intelligible.

C. DISPLAY AND CONTROL DESIGN PRINCIPLES

To understand how displays and controls are integrated into the original design phase of systems, current engineering guides provide a number of display and control design principles which

are used by design engineers to insure the inclusion of good human engineering design practices [5,6]. By combining these design principles with information provided by human engineers with field experience, the following lists of display and control design principles were compiled by NAVAIRTESTCEN for use in categorizing deficiencies in S-3A displays and controls. The following is a list of display design principles [9]:

- Displays should present information as accurately as necessary but no more accurately than required.

- Displays should be available and positioned for efficient system operation.

- Displays should not present erroneous or unreliable information.

- Displays should foster recognition of errors so that errors do not persist.

- Displays should present intelligible information.

- Displays should inform the operation which control to use.

- Displays should be interpretable under various lighting conditions, e.g., strong daylight or night conditions.

- Changing or changed indication should be easy to detect.

- Displays should present indications which are easily verbalized or visualized, thereby reducing operator translations or calculation activities.

- The most important displays should occupy the most prominent area at eye level ±15 degrees.

- Warning and emergency displays should be as near as possible to the central line of sight.

- Displays should inform the operator in which direction to operate the control.

- Displays watched continuously should be in the center of the control panel; those watched only during certain operations should be grouped together farther from the center.

- Display indicators (pointers, markers) should be designed to foster eye scan that goes horizontally left to right or vertically bottom to top.

- Warning and emergency displays should provide unambiguous consistent information with immediate obvious meaning.

- Displays should be free from error-producing features such as cause orientation-reversal and misreading of multi-revolution or multi-pointer dials.

- Displays should inform the operator when, how much and for how long to move the control.

Deficiency reports published on the S-3A were based on data accumulated during the 1973-1974 time period. Displays and controls accounted for 75-percent of the human engineering deficiencies in the S-3A. The types of displays and deficiencies are given in Tables II and III.

The multi-purpose displays are contained in Special Flight Instrument category. The most common engineering design violation was the lack of accurate information being displayed to the operators. This problem was normally caused by poor legibility

of information or the incomplete nature of the displayed information. Specific analysis of the display symbology on the multi-purpose displays is not available for presentation in this report. It is noteworthy that the three most frequently violated principles accounted for 64-percent of the design principle violations. These three violations are related in that they stress the necessity of supplying the operator with accurate, reliable and efficient information. Within the guidelines established in conducting these evaluation, further studies of the current use of the MPD symbology should be conducted to ensure compliance with the basic design principles.

Table II

Display Deficiencies

Display Type	Number	Relative Percent
Special Flight Instrument	26	26.0
Annunciater Lights	31	31.0
Legends	14	14.0
Meters	16	16.0
Event Indicators	7	7.0
Numeric Display	4	4.0
Warning Bells, Buzzers, Horns	2	2.0
	100	100.0

Table III

Relative Percent and Number of Display Principle Design Deficiencies

Display Design Principles	Relative Percent	Number
Displays should present information as accurately as necessary but no more accurately than required.	30.0	33
Displays should be available and positioned for efficient system operation.	21.0	23
Displays should not present erroneous or unreliable information.	13.0	14
Displays should foster the recognition of errors so that errors do not persist.	7.0	8
Displays should present intelligible information.	8.0	9
Displays should inform the operator which control to use.	1.0	1
Displays should be interpretable under varying lighting conditions; e.g., strong daylight or night conditions.	4.0	4
Changing or changed indication should be easy to detect.	3.0	3
Displays should present indications which are easily verbalized or visualized thereby reducing operator translations or calculation activities.	2.0	2
The most important displays should occupy the most prominent area at eye level ±15 degrees.	0.0	0
Warning and emergency displays should be as near as possible to the central line os sight.	2.0	2

Table III(cont.)

Display Design Principles	Relative Percent	Number
Displays should inform the operator in which direction to operate the control.	2.0	2
Displays watched continuously should be in the center of the control panel; those watched only during certain operations should be grouped together farther from the center.	1.0	1
Display indicators (pointers, markers) should be designed to foster eye scan that goes horizontally left to right vertically bottom to top.	0.0	0
Warning and emergency displays should provide unambiguous, consistent information with immediate obvious meaning.	7.0	8
Displays should be free from error-producing features such as cause orientation-reversal on the artificial horizon and misreading of multi-revolution or multi-pointer dials.	0.0	0
Displays should inform the operator when, how much and for how long to move the control.	0.0	0

In analyzing deficiencies that may be present in the multi-purpose displays, one should keep in mind not only the display symbology and the CRT but also the source of information supplied to the display.

"Accuracy" as applied to the information presented to the tactical coordinator often refers to the reliability of the symbology displayed to depict the "real-world" situation. When

the hostile submarine symbol is on the display, the TACCO has to assume that the submarine is really in the location as depicted and the sonobuoy(s) in contact with the submarine are really in the positions that are depicted (i.e., latitude, longitude and relative position with respect to the rest of the symbology). The information on the display is only as good as the information supplied to the tactical display system by the GPDC. Care should be given when proposing discrepancies in the display design when the "accuracy" or "inaccuracy" of the information supplied may be more appropriately credited to the inaccuracy of the navigation sub-program or some other input to the tactical picture. Therefore, "accuracy" as applied to the introduction of color in tactical displays should be well-defined before applying display design principles.

V. USE OF COLOR

The use of color to improve human performance with visual displays is a topic of current interest. The effectiveness of color-coding information in an ASW tactical situation display is undoubtedly a function of the crew task and mission situation involved. With emphasis on the TACCO station in the S-3A, the goal intended to be achieved by the use of color in the ASW tactical display system is to improve the tactical coordinator's ability to effectively accomplish the roles, duties and tasks as outlined before. Considerable work has been and is being done in evaluating the use of color in this medium.

A. VARIABLES FOR CONSIDERATION IN EVALUATING COLOR USE

As in any display design question, it is necessary that careful consideration be given a number of subject areas relative to the use of color. At a minimum it is necessary to examine the following:

1. Objective of display.
2. Operator task(s).
3. Operator capabilities and limitations (e.g., color deficiency).
4. Operator workload.
5. Work environment (e.g., ambient illumination).
6. Colors available with display system hardware.
7. Conventional meaning of colors used (e.g., red - hazard).

8. Use to be made of color (e.g., what function will color serve).

9. Coding combinations (e.g., color + alphanumerics).

Few studies exist, however, which actually consider multiples of the above in a specific application. Most studies available in the literature concentrate on a comparison between color as a coding technique versus some other method of coding (e.g., shapes). However, there is no data available for making valid comparisons, and many available evaluations have been severely restrictive in conditions under which obtained [10]. What is apparent from available research is that a good display in one situation or application may be a poor display in a dissimilar situation or application.

B. GENERAL CONSIDERATIONS

General considerations to follow are based on the use of color in CRT/display designs as an aid to information transfer in terms of an additional level of decision making assistance. Concentration remains on the use of color as a coding technique.

1. Objective/Task

Reference 12 indicates that color is beneficial in search and locate type tasks, but that other coding techniques appear to be more effective in identification tasks. In an identification task (i.e., task is one of identifying a specific feature of a target stimulus) colors can be identified more

accurately than size or shape, but are identified with less accuracy than alphanumerics. Color can be 176% better than size, 32% better than brightness, and 202% better than shape [12]. However, when compared with alphanumerics, color was found to be 48% less accurate than alphanumerics [10]. These percentages indicate a relative comparison. Alphanumerics are presently used in the S-3A displays in tableaus for record keeping, systems alerts and cueing sequences. Specific examples are provided in Appendix C.

Investigation of the effectiveness of coding methods including color, shape, configuration and number in terms of identifying, counting, verifying and comparing indicate colors are better for locating while numbers are better for identifying [12].

The effectiveness of various target-background coding combinations was investigated in Ref. 11. Target codes include eight colors, eight numbers and eight shapes. Background codes included five shades of gray as brightness codes, five patterns, white, gray and five colors. Combinations were studies under target numbers, high and low densities and coding dimensions. Their results were similar to previously cited results in that numbers resulted in better performance on identification and colors better for search performance.

Based on the literature cited, it would appear that color may be beneficial in tasks involving searching for targets and that this superiority would seem to be maintained over

a wide range of conditions and densities. In tasks involving identification the literature suggests that color is inferior to certain other coding techniques (e.g., alphanumerics) and should be avoided. Considerations for color application in the S-3A MPD should be given to the SENSO acoustic display and the radar display as these are directly involved with a search task.

C. THRESHOLDS AND VISUAL ACUITY

The operator's ability to distinguish fine detail is a function of symbol and background color with greatest sensitivity at the red end of the spectrum [13]. It would appear, however, that intensity or luminance is of more importance than color contrast. Reference 14 states that the highest possible color contrast will produce visual acuity roughly equivalent to 35% brightness contrast. As such, visual acuity will be improved much more by increasing brightness than color contrast. At high intensity levels color appears to influence visual threshold in various ways depending upon other factors present in the situation. First, if symbol and background are of the same color, but non-neutral, there can be a slight effect on visual threshold as a result of a shift in spectral balance. In situations where symbol and background are of a different color (hue) there will be a threshold associated with a hue when luminosities are equal. Maximum sensitivity seems to be in yellow/orange and blue/green with reduced sensitivity at extreme blue and red.

Visual acuity with color would appear to be dependent upon a number of factors including color of symbol (target) and background (i.e., contrast), luminance, target size and shape, information displayed, etc. The question of condition which will produce the greatest ability in terms of discriminating fine detail is unclear and demands that attention be paid to each specific application. About the only concrete conclusion is that blue should be avoided as the fovea is blue blind [13].

D. AMBIENT ILLUMINATION

High ambient illumination will tend to reduce symbols to background contrast and as such can be expected to degrade overall performance [13]. Sensitivity increases with adaptation to darkness, and photosensitive substances increase in volume under dark adapted conditions. Reference 12 suggests the following as factors related to sensitivity:

1. Duration of luminance.
2. Average pre-exposure luminance.
3. Size, shape, contrast and viewing time.
4. Color of pre-exposure light.
5. Region of retina stimulated.
6. Physiological status of operator.

At high ambient illumination levels, it reported that response time is fastest at both red and blue ends of the spectrum with slower times reported for yellow to yellow/orange

segment of the spectrum [13]. Therefore, if ambient illumination conditions are high the recommendation would be to use red as the coding color or reduce ambient illumination.

On the other hand, performance is also likely to be degraded in situations involving low levels of ambient illumination. In a dark environment it will be necessary to reduce symbol luminance to a low level in order to maintain dark adaptation. In such situations, it is possible to reduce symbol luminance to a level that prevents operators from perceiving color, thereby rendering color coding useless. However, this is unlikely in the S-3A as the operator can control the symbol luminance.

The possibility of glare represents a further condition that may be present under conditions of high ambient illumination. If illumination is excessive it tends to interfere with visual performance by reducing contrast thereby reducing visibility and/or readibility. Glare, regardless if reflected or specular, can also cause discomfort which can induce subjective fatigue resulting in performance impairment. This is a current problem in the S-3A. "Washout" continues to hamper the pilot and co-pilot in clearly distinguishing the MPD presentations [9].

E. SYMBOL SIZE WITH COLOR DISPLAYS

Symbol size, visual acuity and resolution can be considered as related variables. Resolution is the measure of discrimination of fine detail and is necessarily dependent upon visual

acuity as well as total display resolution. Display resolution is, in turn, dependent upon element or symbol size, bluntness of "pen" drawing the displayed object, the display itself (e.g., contrast, luminance, etc.) and types of information displayed [14]. Any attempt to consider symbol size must include consideration of symbol and color perception and the fact that different requirements exist for each [12]. That is, it is possible to "see" and identify a symbol without the symbol being large enough to enable color recognition. For adequate color perception symbol size varies from 21 to 45 minutes of arc, depending upon the number of colors involved [13].

The following electronic/CRT display requirements, in terms of symbol size, have been suggested [13]:

1. 21 minutes of arc -- minimum.
2. As numbers of colors used increase, minutes of arc increase to 45.
3. Stroke width -- 2 minutes of arc at a minimum.
4. Line width for graphs -- 4 minutes of arc at a minimum.
5. Symbol aspect ratio -- 5:7 or 2:3.

Figure 4 provides an indication of the character size for the tactical plot and peripheral read-outs used in the display for the SENSO and TACCO in the S-3A.

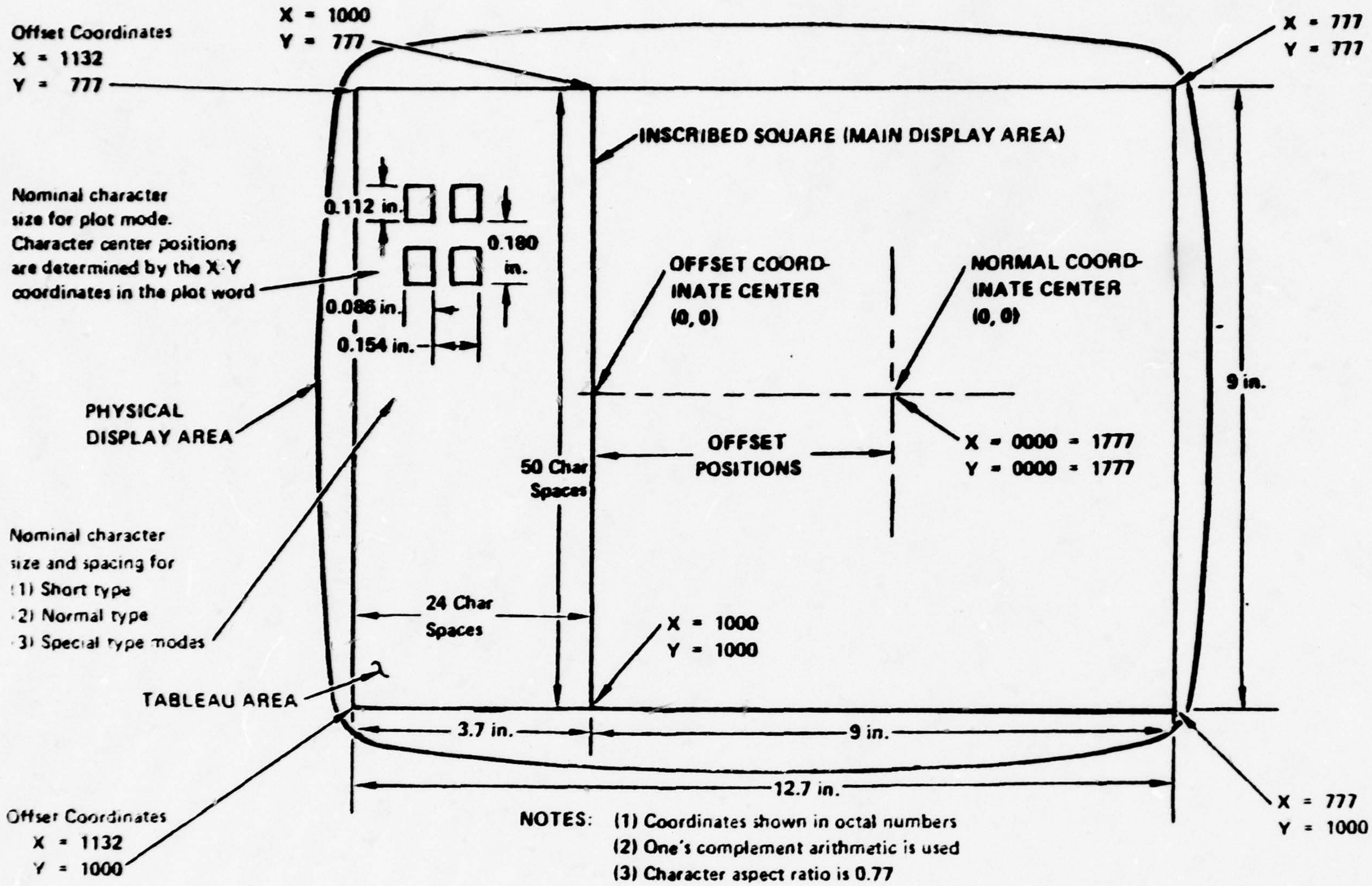


Figure 4

Sensor Operator and Tactical Coordinator Multi-Purpose Display Screen

F. DISPLAY LOCATIONS

Color vision is apparently significantly reduced in the periphery. In fact, the eye is sensitive to color in a very small part of the total field of view (2 degrees) [13]. Therefore, use of color coding in displays which lie outside normal line of sight is questionable. In particular, peripheral displays must restrict the use of red as the periphery is very insensitive to red.

G. COLOR SELECTION

Given that the decision has been made to use color, the next question is what colors and how many? As in all situations involving color, a number of considerations enter into the determination. First, there is general agreement that the number of codes employed should not exceed four [13]. In an applied sense the number of colors selected will depend upon the nature of the task, display limitations (technology), ambient illumination, operator workload, signal criticality, etc. But as a "rule of thumb" three of four colors should be considered as the upper limit.

The following criteria has been suggested in color selection [13]:

1. Maximize wavelength separation.
2. Maximize color contrast.
3. Visibility in specific application.
4. Maintain conventional meaning.

5. Legibility and reading ease.

6. Use highly saturated colors.

Recommendations for color sets to be used are frequently based on laboratory tests and/or involve the capability of a subject to accurately identify a color under good viewing conditions. In the "real world" the tasks required seldom consist of mere color identification, as frequently considerably more complex problems are being encountered than simply identifying a specific color. The question of "blue blindness" has been suggested as an example of the difference between color identification under good viewing conditions and the use of color in a true information transfer situation [13]. That is, the fovea is essentially blue blind and, in addition, is the area most sensitive in fine discriminations. Therefore, a subject may be capable of identifying color, but be unable to make fine discrimination. A recommendation is made that blue symbols be at least 1 degree or more larger than other colors in color coding symbols [13].

Another point in considering color coding involves the question of population stereotypes. Over an extended period of use the colors red, green and yellow particularly, have come to be associated with warning, safe and caution respectively. Any use of these colors should consider these associated meanings and make every attempt to incorporate them into any design effort. Violation of color code convention is inviting error and subsequent performance degradation.

The following recommendations for use of color in CRT/ electronic display design should be adhered to whenever possible [13]:

1. Maximum of four colors.

2. Alphanumerics should be coded with red, white and yellow.

3. Blue should be limited to use involving large areas.

4. White should be used to code peripheral signals.

5. If applicable, follor conventional use of color codes.

H. COLOR CODING AND PERFORMANCE

The real question to be answered is whether or not color coding of electronic/CRT displays will enhance performance sufficiently to be cost effective. As in all areas of research on color coding, considerable controversy surrounds the issue of color coding in CRT type displays in terms of potential enhancement or degradation of operator performance. Available research does suggest that in certain situations and tasks, color can serve to improve performance and may be superior to other coding techniques (e.g., alphanumerics, symbols, etc.). Oda [2] for example, has concluded that computer aided color coded information could reduce reaction time and errors when applied to designs of ASW tactical displays. This conclusion was reached by applying color to the aging of data received by the TACCO in an S-3A. Reference 15 examined resolution, target size, ambient illumination and chroma in a target recognition

type task. Colored targets were recognized faster and fewer errors occurred than with black and white. Reference 11 provided results suggesting color coding had advantages over numbers and symbols in a task of locating targets in noise. Similar results on a similar task were observed in Ref. 16. Applications in the S-3A based on these results would be most effective at the SENSO station in acoustic analysis.

On the other hand there exists considerable evidence to suggest color of no benefit and possibly a detriment in certain types of tasks in specific situations. In Ref. 17 a series of experiments including various tasks concluded color coding was of little decrement or benefit in terms of performance. Target acquisition with color and black and white was investigated in Ref. 18. Observations suggested no benefit of color on detection or range of acquisition. Christ and Corso [16] conducted a series of ten experiments comparing color codes to letters, geometric shapes and digits. Their findings indicated color was not superior in the tasks investigated. Geometric shape coding was comparable in most cases investigated.

Additional work has been conducted on colors as a totally or partially redundant feature (i.e., color used in combinations with a second coding technique). In a totally redundant situation, only one of the coding techniques is necessary for identification. If the two coding functions are only partially corrected, partial redundancy is said to exist.

Krebs [13] has suggested the use of total redundancy to (a) improve symbol visibility and (b) improve symbol discriminability. Partial redundancy should be used to categorize information of more than one level of specificity.

Therefore, it does not appear possible to say color will definitely degrade or enhance performance in any specific situation or task. It does appear that color coding has some advantages in search type tasks. There is little question that observers prefer color coded versus monochromatic displays. This psychological factor cannot be disregarded as an element of consideration. Particularly when one considers subjective fatigue and motivation in terms of performance.

In general, the variables of interest in color display research can be summarized as follows:

1. Color itself (wavelength).
2. Color contrast.
3. Number of colors displayed.
4. Brightness contrast.
5. Color vision deficiency.
6. display density.
7. Exposure time.
8. Nature of task(s).
9. Operator workload.
10. Population stereotype.
11. Coding combination (redundancy).

12. Psychological aspect of presenting information in color as opposed to black and white.

13. Display position.

The present "state of the art" does not allow for a definite statement regarding the use of color in CRT display design. Performance does not appear to be significantly influenced under most situations with the use of color. Color displays seem to be most advantageous in search and locating type tasks, although available data does not make a particularly strong case for color with the search and locate task. One significant limitation to color use is the small number of coding dimensions available (four at maximum). Therefore, any attempt to apply color coding must be limited to information possessing a maximum of four conditions. If used, it would appear color should be used in a categorization or classification scheme quite small in scope.

The question of color use is not well documented. Based on available research the question of cost effectiveness must be considered, particularly in view of the rather large cost of producing color displays for airborne use as compared to the present system. Before any statement relative to color coding in CRT display design can be made, additional work is necessary and may be found to await technological outcomes in color display design.

VI. CONCLUSIONS AND RECOMMENDATIONS

Justification for adaptation of color-coding in the S-3A multi-purpose displays is an interesting problem in that current research does not take into account the amount and variety of information that the displays present, the relative quickness in which the information can change, the capabilities of the operators to instantaneously change display mode from a search and detection mode to a broad tactical picture, and the decision making processes that take place in this unique environment of airborne ASW.

In adapting color to tactical display symbology, a number of variables must be taken into consideration. To obtain the maximum benefit from the use of color initially, it should be used in those areas that the highest criticality and frequency percentiles in the ordered ranking of the TACCO's duties and coincide with those activities that account for the areas that consume the majority of the TACCO's time. Color should be introduced into the MPD, where possible, as a means of reducing the present display design principle deficiencies. Those areas that have the highest number of deficiencies should be accounted for initially. In correcting these deficiencies, emphasis should be placed on the definitions of the human engineering deficiencies adopted by NAVAIRTESTCEN for standardization purposes. Emphasis should also be placed on the present display

induced operator errors with the goal being to eliminate these errors without adding the possibility of future problems based upon the addition of color.

The colors for use in aircrew station signals are specified in Ref. 19. If color-coding is to be adapted to current symbology in use in the tactical display system for the tactical plot presentation, the associated meaning of the colors specified should be considered. For basic fix symbology, the following meanings are recommended:

1. Red -- Hostile -- Immediate Threat.
2. Yellow -- Unknown -- Possible Threat.
3. Green -- Friendly -- No Threat.

Considerations for color-coding other symbology should be done in a similar manner.

1. Sonobuoy in contact with a hostile submarine -- Red.
2. Sonobuoy in contact with an unknown -- Yellow.
3. Sonobuoy in contact with a friendly -- Green.

This color meaning could also be applied to DIFAR bearing lines, ESM bearing lines and active sonobuoy range circles. For tactical plot information other than basic fix symbology, the assignment of a color to target data would possibly have to be done by the sensor operator through a cueing sequence and the resulting color assignment would be based on the operator's interpretation of the "raw" data presented to him. Then the question of what software alterations are required to

allow an operator to assign the color or can this be done with a cueing sequence currently available to the operator?

Literature indicates that color-coding is best suited for "search and detection." The tactical plot presentation in the S-3A is not used primarily for this task. "Search and detection" is more appropriately applied to the tasks of an acoustic sensor operator or a radar operator. Both of these individuals are constantly involved in searching for a target in the presence of background noise and identifying the target based on the detected signal. If color-coding is to be used as an aid in initial detection the associated meaning of the color should coincide with the meaning of colors presently used in aviation displays (i.e., Red - warning, Yellow - caution, Green - normal). The time-value meaning of a color as referred to in Ref. 2 should be re-evaluated with the following meanings as possibilities:

1. Red -- Warning -- New data (target) -- Immediated Action Required.

2. Yellow -- Caution -- Aging data (target) -- Possible Action Required.

3. Green -- Safe (Normal) -- Aged data (target) -- Appropriate Actions have been completed and no other action required at this time.

These meanings could aid both the radar operator and the acoustic sensor operator in initial detection and in establishing priorities on targets to be analyzed. Color in this case

should not be used to replace alphanumerics that presently are being used or are being considered for use in the future as an aid to initial detection and classification. More appropriately, it should be used in conjunction with a "raw" data display as an aid in distinguishing a signal in a clutter of background noise.

Recommendations are that a maximum of four colors in a display design should be adhered to. If four colors are used for coding, additional questions arise based on the present S-3A MPD design:

1. Will the brightness control in the present MPD control all of the colors or will separate brightness controls be required for each color?

2. If only one brightness control is available, will the "sharpness" of one color of symbol as opposed to another color (i.e., red versus green) deteriorate at some point in the range of the brightness control?

3. The questions above should be applied to the present focus control. Will one color focus better than another? Will more than one focus control be required?

4. What is the limit on the number of additional controls required to maintain a presentation that would properly serve its purpose? At some point the operator may be too busy establishing a useful display to properly accomplish his primary task.

5. Should color assignment to symbology in a tactical display be operator selectable or provided automatically by the GPDC?

6. If the option of selecting a color for assignment to a symbol is left to an operator, will the operator become unnecessarily burdened with a decision of which color to use when the emphasis on decision making should be in some other area?

7. If the computer selectability of color is used, how much of the computer memory capabilities will be required for this function as opposed to the possibility of using that portion of the memory for additional aids to data processing?

8. Will the colors used for coding purposes in the ambient lighting environment in the aft two seats of the S-3A have the same degree of success in the displays for the pilot and co-pilot? Will be problem of "wash-out" become even more pronounced with color-coded symbology?

9. Are the costs of implementing a successful color-coding scheme justifiable?

10. In relation to the previous question, how is cost effectiveness to be measured?

Based on the available literature, indications are that the use of color-coding would be beneficial in acoustic analysis and in target detection in a raw radar display. There is insufficient evidence available to strongly indicate that the use of color in tactical display symbology would aid the tactical

coordinator in the S-3A in successfully localizing and destroying an enemy submarine.

Consideration should be given to testing a multi-purpose display with color-coding in one of the weapon systems trainers presently in operation at NAS North Island, California or NAS Cecil Field, Florida. All aspects of any mission the S-3A would encounter could be simulated and the influence of color on the success of an S-3A crew could be more accurately evaluated than if the same display was evaluated in a laboratory. Hopefully, this would provide some data base for stating that an S-3A crew with a color-coded display can successfully complete a mission faster and more efficiently than the same crew with the present display. This seems to be the only method of determining as closely as possible a true measure of cost effectiveness.

APPENDIX A

Threat Background

A. THE THREAT

Since World War II, the USA and the USSR have both expended considerable effort and monies in attempts to upgrade both quality and quantity of submarine forces. In January 1955, the USS NAUTILUS began a new era in submarine warfare by getting underway on nuclear power. In December 1959, the first Polaris missile submarine, the USS GEORGE WASHINGTON, was commissioned. During this time period the USSR was concentrating on quantity of submarines with less attention being devoted to quality and performance. Soviet nuclear submarine construction began in 1959 and by 1969 they had a total of about 50 modern submarines [20].

With the invention and capabilities of nuclear powered submarines the mission of the Soviet submarine force expanded beyond the "defense of the homeland" [21]. Two basic missions emerged from this vast increase in endurance and speed for the submarine. The first mission was that of the ballistic missile-carrying submarine, with the missile pretargeted for designated areas in the United States and her allies. With the limitation of targeting procedures for these missiles, they possessed little threat to operational forces at sea, but could only be targeted for stationary known positions.

The second mission, which had always concerned the Soviets, was stopping an invading enemy. The nuclear powered submarine posed a much more awesome threat than the diesel electric submarine. With its virtually unlimited range, the nuclear submarine could now leave its home waters and attack the enemy at a much greater range and, preferably, long before the enemy was within striking distance of the homeland [21].

The United States Navy was now faced with an oceanwide threat to its CVA's from the Soviet submarine force. Collins [22] places alarming emphasis on the current Soviet cruise-missile threat to the aircraft carriers and weaknesses in US antisubmarine warfare.

To help meet the threat of the cruise-missile submarine, the United States Navy authorized the production of the S-3A antisubmarine weapon system. The S-3A is the primary carrier-based operational ASW aircraft capable of performing all phases of the ASW role. It is one part of a total counter-threat philosophy generated by the development of quieter and faster nuclear submarines. The heavier than air-search (VS) community, for whom the S-3A was built, is tasked with the responsibility of maintaining the national commitment to deter forceful aggression by the constantly improving enemy submarines.

B. ANTISUBMARINE WARFARE (ASW)

Airborne antisubmarine warfare involves at least four activities that proceed in a logical sequence; search, detection,

localization and attack. An optional tracking phase of hours and even days can occur between localization and attack. During peacetime operations, accurate tracking of submarines is the goal of airborne ASW elements.

1. ASW Mission

Four primary ASW missions for the S-3A, discussed in Ref. 2, are; (a) persistent search and attack, (b) contact investigation, (c) submarine transit identification zone, and (d) protection of high priority at-sea operations. Two secondary missions, surface surveillance and mining operation, are well within the capabilities of the S-3A.

a. Persistent Search and Attack

This mission consists of a concentrated effort to localize and destroy all submarines in a given area of responsibility. The mission involves laying a sonobuoy field to encompass a specified area of probability and maintaining a continuous surveillance of sonobuoys until the enemy submarines are destroyed or the operation is terminated. To successfully complete the mission total sensor utilization is a requirement.

b. Contact Investigation

Intelligence information defines a specific probability area for the location of a submarine for this mission. The area of interest depends upon submarine type, datum error and time of arrival of the ASW aircraft on station. The area of interest is usually smaller than in the mission discussed above. Contact investigation implies the fastest possible

reaction time, a concentration of effort over a relatively small area and generally a shorter span of effort than does the search and attack mission.

c. Submarine Transit and Identification Zone

This mission requires the establishment of a barrier type of sonobuoy field constructed to maximize the probability of detection of a transiting submarine. It may or may not include the destruction of contacts, and may or may not involve assisting forces such as friendly ASW submarines operating adjacent to the sonobuoy field.

d. Protection of High Priority At-Sea Operations

This mission has two modes of operation. The first is the establishment of a moving sonobuoy field protecting high priority forces (amphibious task force or high value convoys) transiting through ocean areas where submarines may operate. The second mode involves establishment of a sonobuoy field to protect a static area such as an amphibious landing zone. In either case, the operation continues as long as the protected force is subject to submarine attack.

e. Surface Surveillance Mission

The surface surveillance mission is conducted for the purpose of tracking all surface contacts in a given area, determining the identity of the contacts, relaying surface plot information to the surveillance commander, reporting and investigating new contacts, and dropping contacts leaving the area. The surveillance mission is generally long-term in duration

and utilizes radar, infrared and electronic support measures as primary sensors. It requires the generation of a large number of aircraft tracks to provide a high degree of coverage and a high probability of early detection of new contacts. The flight path in the search pattern is somewhat random.

f. Mining Operations

The S-3A is configured to carry aircraft-type mines and can be tasked to mine an area of high strategic importance where other forces could not accomplish the task because of distance from friendly bases or other operation constraints. The task requires precise navigation and ballistic calculations to ensure accurate mine emplacement. In addition to the use of accurate geographical navigation systems, non-acoustic sensors (FLIR and radar) can be used to fix aircraft location with respect to terrain features.

C. THE WEAPON SYSTEM

The S-3A airplane is a subsonic, four-place, twin-engine, antisubmarine warfare (ASW) airplane designed for land- and carrier-based missions. It carries surface and sub-surface search equipment with integrated target acquisition and sensor coordinating systems which can collect, process, interpret and store ASW sensor data. The heart of the integrated avionics weapons system is the General Purpose Digital Computer (GPDC). The crew, consisting of a pilot, co-pilot (non-acoustic sensor operator), tactical coordinator (TACCO), and sensor operator

(SENSO), communicates with the GPDC through individual multi-purpose displays and integrated control systems. Information is supplied to the GPDC by acoustic and non-acoustic sensors, navigation and communication equipment, and the crew. Peripheral avionics sub-systems include the radar, magnetic anamoly detection (MAD) system, forward looking infrared system (FLIR), electronic systems, armament control system and communication systems (including Data Link 11). The airplane is designed to carry and deliver a wide variety of weapons in the bomb bar and on two wing pylon stations. Externally loaded sonobuoys are carried in and deployed from the aft fuselage sonobuoy compartment.

1. <u>Crew Station Configurations</u>

On an ASW mission the S-3A is operated by a crew of four with the general arrangement as depicted in Fig. A-1. The pilot and co-pilot seats are arranged side-by-side in the forward cabin. The co-pilot has dual flight controls and is equipped to control the non-acoustic sensors, navigation equipment and communication hardware.

The TACCO station, located aft of the co-pilot station on the right side of the aircraft, comprises the systems necessary for control and tactical display of the mission. The SENSO station, located aft of the pilot station on the left side of the aircraft, contains the controls and displays for acoustic and non-acoustic sensor systems necessary for the successful completion of the SENSO's portion of the mission. The

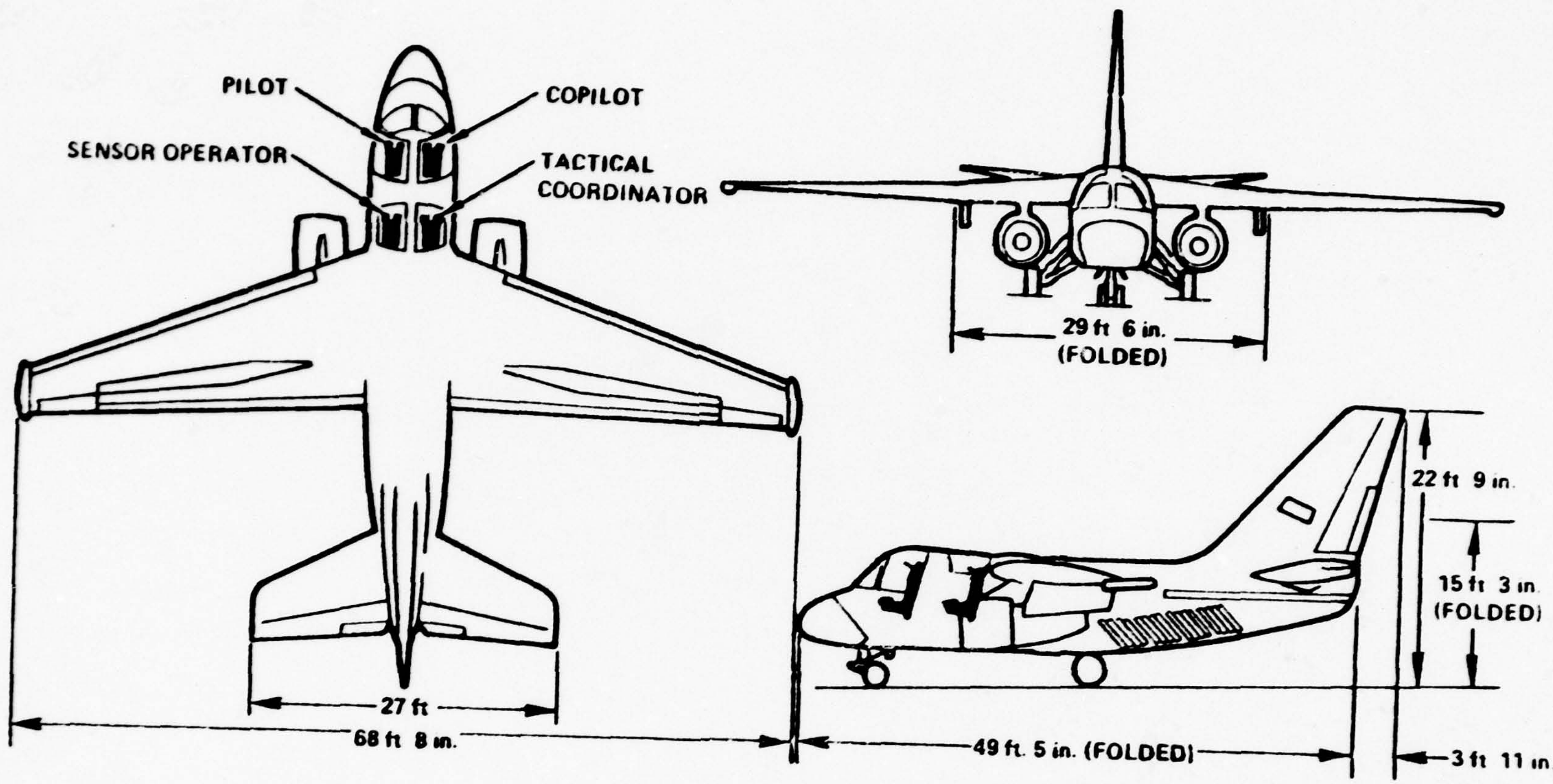


Figure A-1

S-3A Airframe Outline

arrangement of the crew stations with the equipment that will be of specific interest in this paper are shown in Fig. A-2.

The specific responsibilities for each member of the crew are given in Ref. 23 and will not be covered here. The responsibilities of the TACCO were covered in detail in Chapter III. This is the station of interest in work presently being done on adapting color-coding to S-3A displays [2].

D. DATA PROCESSING SYSTEM

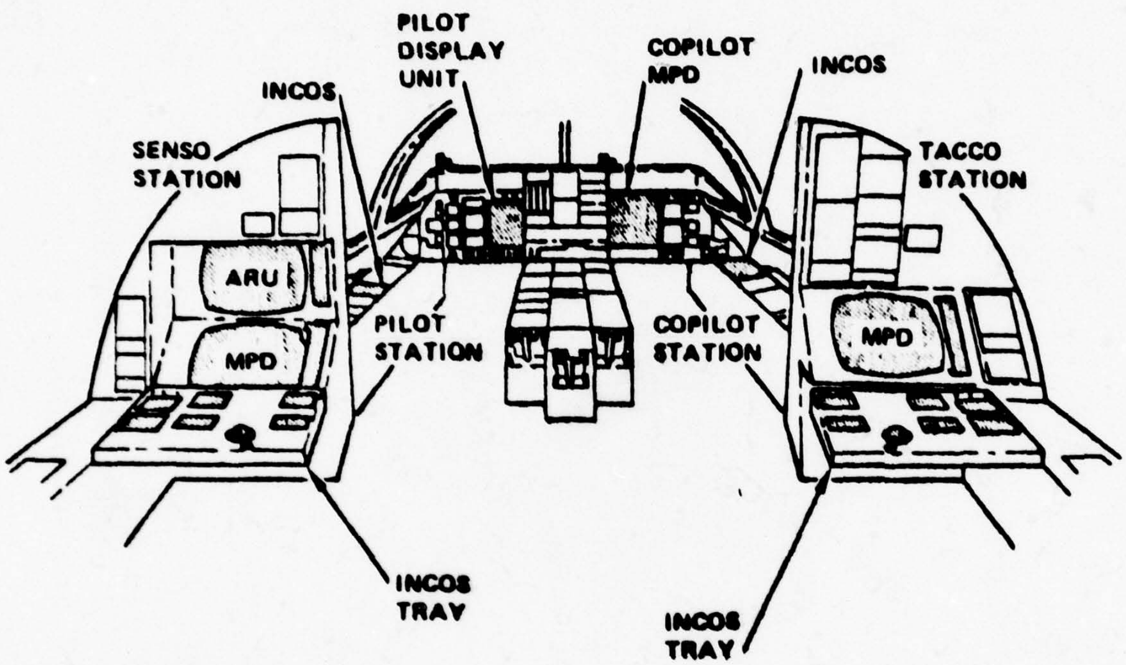
The heart of the S-3A as a weapons system is the Data Processing System (DPS). The DPS receives, processes, analyzes and correlates a large volume of data from the ASW sensors and the operators, displaying the results to the operators.

1. General Purpose Digital Computer (GPDC)

The UNIVAC 1832 general purpose digital computer is a general purpose, stored program computer which controls the weapons system. The GPDC receives data inputs from ASW sensors either directly or from operators through the Integrated Control System (INCOS). The GPDC processes this data to control the avionic systems and display information to the operators through the Tactical Display System (TDS).

2. Tactical Display System (TDS)

The TDS is the primary means the GPDC uses to present information to the operators. There are three multi-purpose displays which, with a few exceptions, can present all the pertinent ASW data developed with the aircraft. There is one pilot

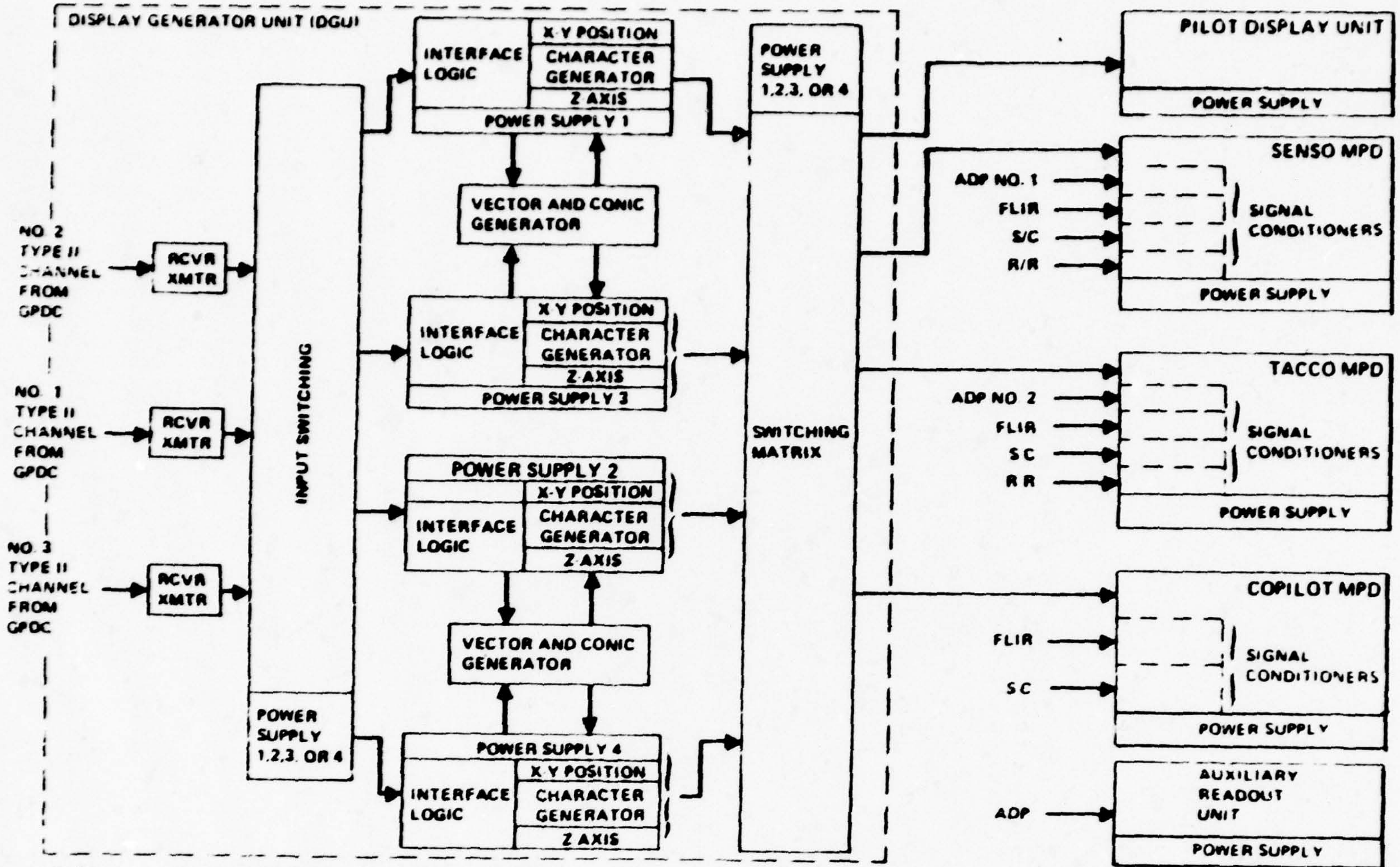


SENSO	–	SENSOR OPERATOR
ARU	–	AUXILIAR READOUT UNIT
MPD	–	MULTIPURPOSE DISPLAY
INCOS	–	INTEGRATED CONTROL SYSTEM
TACCO	–	TACTICAL COORDINATOR
TDS	–	TACTICAL DISPLAY SYSTEM

Figure A-2

Arrangement of Crew Stations

display which is limited to displaying the tactical plot format. The Auxiliary Read-out Unit (ARU) at the SENSO station displays acoustic data only. The TDS transforms digital and analog signals from the GPDC into pictorial displays of raw radar, scan converted radar, FLIR, MAD and acoustic data. The TDS also presents words, numbers and a plot depicting aircraft, sonobuoy and contact positions, lines of bearing, range radii and other graphic symbols to illustrate the tactical situation. The symbols and usage are listed in Appendix C. Figure A-3 shows the TDS interface with the GPDC, FLIR, radar and Acoustic Data Processor (ADP) systems. Data display capabilities for the five TDS display units are summarized in Fig. A-4.



GPDC - GENERAL PURPOSE DIGITAL COMPUTER
SENSO - SENSOR OPERATOR
TACCO - TACTICAL COORDINATOR
ADP - ACOUSTIC DATA PROCESSOR
FLIR - FORWARD LOOKING INFRARED
SC - SCAN CONVERTER
RR - RAW RADAR
MPD - MULTIPURPOSE DISPLAY

Figure A-3

Tactical Display System Functional Block Diagram

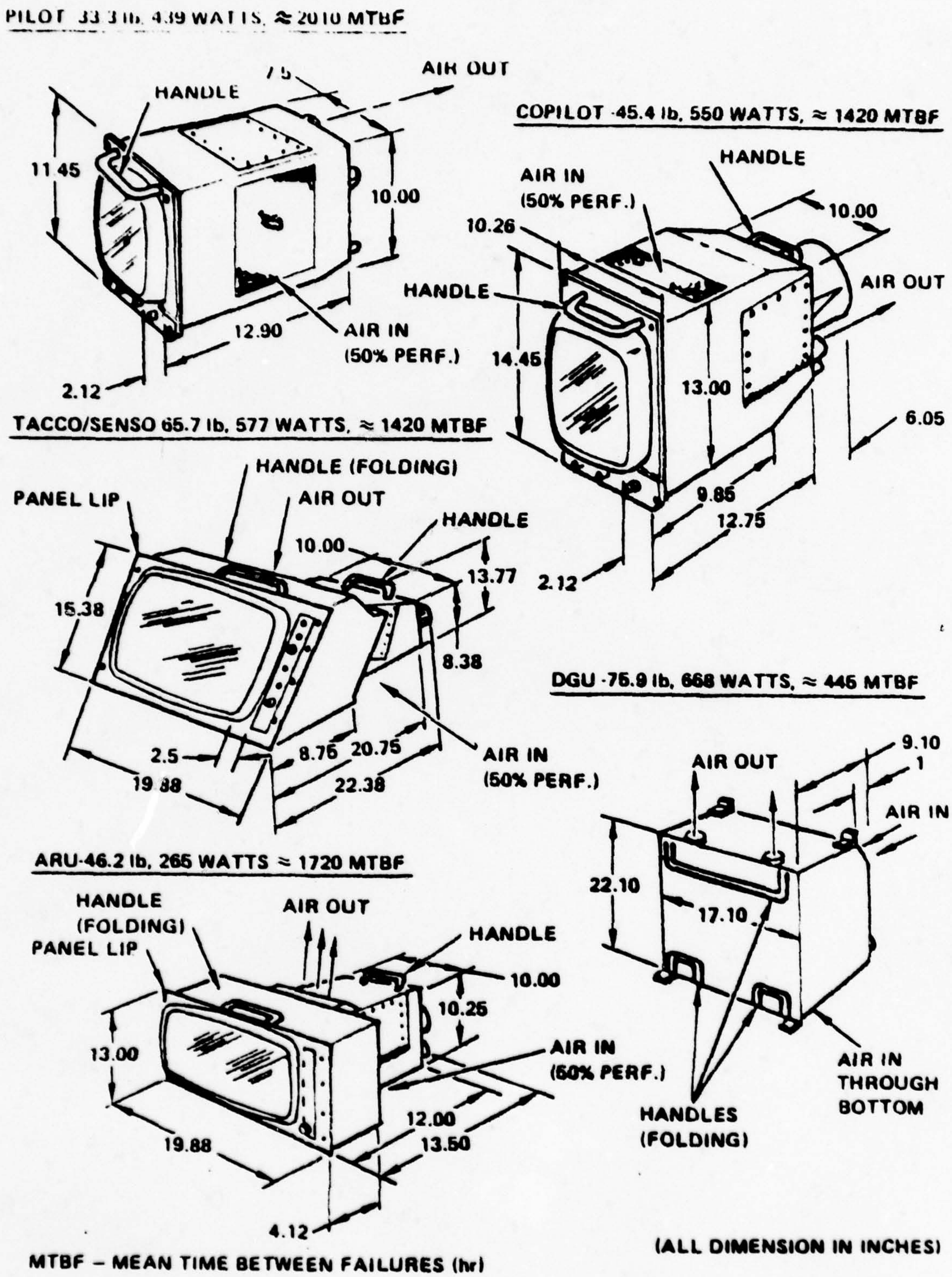


Figure A-4

Tactical Display System Component for the S-3A

APPENDIX B

S-3A Tactical Coordinator Task Analysis

1.0 Conduct mission planning

1.1 Gather necessary briefing information

1.1.1 Gather briefing information from Air Wing brief

1.1.2 Gather briefing information from TSC brief

1.2 Determine utilization of sensors

1.2.1 Determine optimum sonobuoy usage

1.2.1.1 Determine type of sonobuoy to be utilized

1.2.1.2 Determine optimum sonobuoy life selection

1.2.1.3 Determine optimum hydrophone depth selection

1.2.1.4 Determine appropriate sonobuoy pattern

1.2.1.5 Determine sonobuoy spacing required

1.2.1.6 Determine any implications on flight profile

1.2.2 Determine utilization of ESM

1.2.2.1 Determine ESM parameters

1.2.2.2 Determine ESM processing priorities

1.2.2.3 Determine any implications on flight profile

1.2.3 Determine utilization of radar

1.2.3.1 Determine initial search parameters

1.2.3.2 Determine search employment and EMCON considerations

1.2.3.3 Determine any implications on flight profile

1.2.4 Determine utilization of FLIR

1.2.4.1 Determine weather parameters

1.2.4.2 Determine employment plan

1.2.4.3 Determine any implications on flight profile

1.2.5 Determine utilization of MAD

1.2.5.1 Determine MAD parameters

1.2.5.2 Determine MAD employment plan

1.2.5.3 Determine any implications on flight profile

1.3 Determine COMM configuration

1.3.1 Determine controlling agencies

1.3.2 Determine DATA LINK configuration

1.4 Determine utilization of weapons/stores

1.4.1 Determine utilization of search stores

1.4.1.1 Determine contents of stores load

1.4.1.2 Determine stores release parameters

1.4.1.3 Determine implications on flight profile

1.4.2 Determine utilization of KILL stores

1.4.2.1 Determine weapon parameters

1.4.2.2 Determine weapon suitability per target type

1.4.2.3 Determine implications on flight profile

1.5 Conduct pre-flight planning

1.5.1 Determine search plan

1.5.1.1 Determine area of search

1.5.1.2 Determine target and analyze target data

1.5.1.3 Determine primary sensor(s) for mission

1.5.1.4 Determine optimum utilization of all sensors

1.5.1.5 Determine mission tactics

1.5.2 Determine NAV plan

1.5.2.1 Determine GEO NAV plan

1.5.2.1.1 Determine route of flight

1.5.2.1.2 Determine flight restrictions and effect on sensor utilization

1.5.2.1.2.1 Determine depart force procedures

1.5.2.1.2.2 Determine warning areas

1.5.2.1.2.3 Determine return to force procedures

1.5.2.1.3 Determine Bingo profile

1.5.2.1.4 Determine NAV update possibilities

1.5.2.1.5 Determine MAG VAR

1.5.2.2 Determine TAC NAV plan

1.5.2.2.1 Determine fuel spec

1.5.2.2.2 Determine flight restrictions in the TAC area

1.5.2.2.3 Determine NAV update possibilities

1.5.2.2.4 Determine REINIT procedures

1.5.3 Participate in crew brief

1.5.3.1 Conduct mission tactical brief

1.5.3.2 Determine mission restrictions on tactical employment of the sensors

1.5.4 Review A/C discrepancy log

1.5.4.1 Determine the effect of A/C discrepancies on the mission

1.5.5 Conduct pre-flight of personal survival gear

2.0 Conduct pre-flight

2.1 Conduct exterior pre-flight

2.1.1 Verify contents of each SLC

2.1.2 Verify proper loading of KILL stores

2.1.3 Complete exterior pre-flight checklist

2.2 Conduct interior pre-flight

2.2.1 Conduct ejection seat pre-flight checklist

2.2.2 Conduct inspection of electronics bay

2.2.3 Complete interior pre-flight checklist

3.0 Conduct A/C start procedures

3.1 Strap in

3.2 Complete pre-start checklist

3.3 Establish and maintain optimum ICS configuration

4.0 Initialize systems

4.1 Select and analyze MPD test patterns

4.2 Load operational program in the GPDC

4.2.1 Inset mission essential data

4.2.2 Reinitialize individual subsystems

4.2.3 Verify stores load

4.2.4 Verify Data Link configuration

5.0 Conduct take off/launch procedures

5.1 Complete after start checklist

5.2 Complete take off checklist

5.3 Monitor navigation system through appropriate tableaus

6.0 Conduct enroute procedures

6.1 Ensure two-way voice communications with controlling agencies

6.2 Conduct transit NAV

6.2.1 Provide command steering to operating area

6.2.2 Update GEO NAV as appropriate

6.3 Monitor program status

6.3.1 Interpret program degradations

6.3.2 Provide analysis of mission limitations based on program degradations

6.4 Monitor system status

6.4.1 Interpret system degradations

6.4.2 Provide analysis of mission limitations based on degraded systems

6.5 Provide tactical options available with program and system degradation

6.6 Assemble and transmit KILO report

7.0 Conduct on-station procedures

7.1 Deploy BT buoy

7.1.1 Update PRAT tableau

7.2 Establish sonobuoy pattern as briefed

7.3 Provide command steering information for deploying pattern

7.4 Deploy sonobuoy pattern

7.4.1 Perform deployment on-line

7.4.2 Perform deployment off-line (if required)

7.4.3 Monitor release parameters

7.4.4 Determine sonobuoy tuning

7.4.4.1 Tune omni

7.4.4.2 Tune type

7.4.5 Determine SRS or TACNAV plot stabilization

7.5 Assist SENSO in establishing optimum processing capabilities

7.5.1 Determine optimum monitor cycle

7.5.2 Determine optimum ADP configuration

7.6 Employ non-acoustic sensors

7.6.1 Employ radar

7.6.1.1 Select proper search mode

7.6.1.2 Designate area of search

7.6.1.3 Classify and fix targets

7.6.1.4 Enter target into system

7.6.1.5 Communicate contact report to controlling agencies

7.6.1.6 Enter contact on NDTS Link if aqpropriate

7.6.2 Employ ESM

7.6.2.1 Ensure proper scan parameters entered

7.6.2.2 Recognize and respond to system detection

7.6.2.3 Classify target

7.6.2.4 Employ appropriate tactics

7.6.2.4.1 Triangulation

7.6.2.4.2 Fixing

7.6.2.4.3 Tracking

7.6.2.5 Communicate contact report to controlling agencies

7.6.2.6 Enter contact on NDTS Link if appropriate

7.6.3 Employ FLIR

7.6.3.1 Select proper search mode

7.6.3.2 Designate area of search

7.6.3.3 Detect and ID target

7.6.3.4 Communicate contact report to controlling agencies

7.6.3.5 Enter contact on NDTS Link if appropriate

7.6.4 Employ MAD

7.6.4.1 Extend MAD boom

7.6.4.2 Select proper mode

7.6.4.3 Recognize and respond to system detection

7.6.4.4 Employ appropriate tactics

7.7 Establish surface plot

7.7.1 Perform TAC PLOT management

7.7.1.1 Fix designate

7.7.1.2 Generate track

7.7.1.3 Modify target category

7.7.1.4 Transfer item

7.7.1.5 Generate special patterns

7.7.1.6 Destroy data

7.7.1.7 Perform table extract

7.8 Perform localization

7.8.1 Determine area of probability

7.8.1.1 Logical comparative LOFAR

7.8.1.2 LOFIX

7.8.2 Determine line of position

7.8.2.1 HYFIX

7.8.3 Deploy and expand DIFAR patterns

7.8.4 Employ all sensors in solving ambiguities

7.8.5 Ensure plot stabilization

7.8.5.1 SRS

7.8.5.2 TAC NAV

7.8.6 Obtain criteria for deployment of active pattern

7.8.7 Perform tracking

7.8.7.1 Passive

7.8.7.1.1 DIFAR

7.8.7.1.2 Mini-barriers

7.8.7.2 Active

7.8.7.2.1 RO buoys

7.8.7.2.2 CASS buoys

7.8.7.2.3 MAD

7.9 Establish attack criteria

7.9.1 Obtain passive attack criteria

7.9.1.1 Mini-barriers

7.9.1.2 CPA's

7.9.2 Obtain active attack criteria

7.9.2.1 RO

7.9.2.2 CASS

7.9.3 Obtain attack criteria using MAD

7.9.4 Obtain attack criteria using visual

7.10 Employ KILL stores

7.10.1 Employ on-line KILL stores

7.10.1.1 Verify ACP configuration

7.10.1.2 Select appropriate weapon(s)

7.10.1.3 Ensure bomb bay open

7.10.1.4 Insert weapon(s) release position

7.10.1.5 Monitor release parameters

7.10.1.6 Release weapon(s)

7.10.1.7 ID and respond to ARMCOS failures

7.10.1.8 Communicate with controlling agencies

7.10.2 Employ special weapons

7.10.2.1 Configure ACP and AMAC

7.10.2.2 Select appropriate weapon(s)

7.10.2.3 Ensure bomb bay open

7.10.2.4 Insert weapons release position

7.10.2.5 Monitor release parameters

7.10.2.6 Release weapons

7.10.2.7 ID and respond to ARMCOS failures

7.10.2.8 Communicate with controlling agencies

7.11 Maintain re-attack criteria

7.11.1 Passive

7.11.2 Active

7.11.3 MAD

8.0 Conduct return procedures

8.1 Communicate

8.1.1 Communicate with controlling agency

8.1.2 Communicate with supporting unit

8.1.3 Communicate with relieving unit

8.2 Navigate

8.2.1 Conduct transit NAV

8.2.2 Provide FTP for home plate

8.2.3 Monitor NAV parameters

8.3 Accumulate mission data

8.3.1 Perform tableau extracts

9.0 Conduct approach procedures

9.1 Complete approach checklist

9.2 Monitor approach procedures

10.0 Conduct landing procedures

10.1 Complete landing procedures

10.2 Monitor landing procedures

11.0 Conduct post-landing procedures

11.1 Complete systems shutdown

11.2 Monitor taxi procedures

12.0 Conduct shutdown procedures

12.1 Ensure GPDC shutdown

12.2 Complete secure checklist

12.3 Retrieve required tapes and equipment for debrief

13.0 Participate in debrief

13.1 Complete maintenance register/software documents

13.2 Disseminate iformation to CVIC/TSC

13.2.1 Disseminate sensor information

13.2.2 Disseminate NAV information

13.2.3 Disseminate photographic information

13.2.4 Disseminate contact analysis information

13.3 Participate in crew debrief

13.3.1 Review tactical analysis of mission

APPENDIX C

OPERATIONAL PROGRAM DISPLAY SYMBOLOGY

HOOK

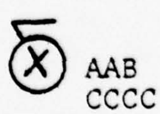
The hook symbol position is controlled by the operator through trackball movements. The operator uses the hook as a pointer for designating positions of symbols on the display.

AIRCRAFT

The aircraft symbol represents the aircraft current position and moves over the display area with direction and speed proportional to the aircraft ground track. A ½-inch vector extends from the symbol center and represents the current direction of the aircraft ground track.

Note

> On scan-converted or raw radar PPI displays, and when selected by the pilot, the aircraft ground track vector is 4-inches long.



SONOBUOY

The sonobuoy symbol marks a sonobuoy position on the tactical plot display. It is also used to annotate various acoustic displays. The sonobuoy symbol has several associated letters and numbers which describe:

- Sonobuoy type (X) where X can be:

  D - DIFAR
  L - LOFAR
  C - CASS
  S - DICASS
  R - RO (SSQ-47)
  B - Bathythermal

• RF channel (AA) where AA can be 01 through 31.

• Processor tuning status (B) where B can be:

(blank) - not tuned
T - Sonobuoy tuned as its type
L - LOFAR/DIFAR sonobuoy tuned as LOFAR

• Estimated time when buoy will die (CCCC). This annotation is only displayed when the INCOS AMPLFY function has been activated.

• If the TN AMPLFY function is active, CCCC represents a four-digit (octal) data link track number.

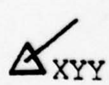
• On the pilot's display, only the sonobuoy RF number is displayed. The left digit of the RF number corresponds to buoy position.

SMOKE

The smoke symbol marks smoke positions on the tactical plot display.

SUS

The sound underwater signal (SUS) symbol marks the computed position where a SUS splash point occurs after the SUS is dropped from the aircraft.



FLY-TO-POINT

The fly-to-point (FTP) symbol is used to mark a geographic position toward which the operator wants the aircraft to proceed. A designated FTP has a ½-inch vector extending from the symbol center in the direction the operator wants the aircraft to over-fly the FTP. The associated letters and numbers describe:

• FTP type (X) where X can be:

W - Weapon
E - Expendable
I - Intercept
N - Normal
M - Monitor

·FTP priority (YY) where YY is a one- or two-digit number representing the FTP priority. The pilot display is an exception to this rule. On the pilot display the priority designation is absolute regardless of FTP type and sequence within the type.

[ ] [A] [B]

REFERENCE MARK

The reference mark is used as a general purpose mark to flag points of interest on the tactical plot. If the mark is used to designate the position of the aircraft as it flys over a point, the letter A appears in the symbol center and it is called an "aircraft mark". A buoy mark symbol (a buoy drop point suggested by the Entrapment Pattern Function) consist of the hookable letter B in the symbol center.

⊗ X
CCCC

WEAPON SPLASH POINT

The weapon splash point symbol marks the calculated position where a weapon strikes the water.

·Weapon type (X) where X can be:

T - Torpedo
M - Mine
B - Bomb
R - Remote

·Estimated time of splash (CCCC) is only displayed when the INCOS AMPLFY function is active.

·If the TN AMPLFY function is active, CCCC represents a four-digit (octal) data link track number.

OT

ON TOP

The on top position is used to mark the position directly below the aircraft when the ON TOP switch is pressed. The O represents the precise position location. Only one on top position symbol can be displayed at a time.

 XXXX
YYYY

DATUM (LOCAL OR REMOTE)

The datum symbol marks a locally entered or a data link received contact position on the tactical plot. The associated numbers describe:

- Track number (XXXX) where XXXX ranges from 0200 through 7776 (octal).

- Designation time (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

- If TN AMPLFY function is active, YYYY represents a four-digit (octal) data link track number.

- If the datum symbol has a superimposed K, the contact is data link received.

Note

Track numbers and contact numbers are designated in the octal number system.

 XXXX
YYYY

LOST CONTACT

The lost contact symbol is used to mark the last known position of the lost contact. The associated numbers describe:

- Track number (XXXX) where XXXX ranges from 0200 through 7776 (octal) is displayed if lost contact is locally entered. Track number is blank if the symbol is remote.

- If TN AMPLFY function is active, YYYY represents a four-digit (octal) data link track number.

•If INCOS AMPLFY function is active, YYYY represents a three-digit (YYY) speed of track.

•A superimposed letter on the symbol indicates the source designator where:

R - Radar
E - ESM
V - Visual
F - FLIR
M - MAD
K - Remote
A - Active
T - TACCO Designate
S - DICASS
P - PAC
BLANK - Dissimilar Sources

 YYYY

DOWNED AIRCRAFT (LOCAL OR REMOTE)

The downed aircraft symbol is used to mark the position of an aircraft crash. It flashes continuously. The associated numbers describe:

•Designation time (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

•If TN AMPLFY function is active, YYYY represents a four-digit (octal) data link track number.

 YYYY

DISTRESSED VESSEL (LOCAL OR REMOTE)

The distressed vessel symbol marks the position of a vessel with an emergency. It flashes continuously. The associated numbers describe:

•Designation time (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

•If TN AMPLFY function is active, YYYY represents a four-digit (octal) data link track number.

 XXXX

CV

The CV symbol is a data link or operator entered symbol which designates the position of the carrier. The numbers (XXXX) indicate the time the symbol was received over data link or the last computed update.

 XXXX
YYYY

NON SUB (LOCAL OR REMOTE)

The non sub symbol marks the position of a contact which has been evaluated as nonsubmarine. The associated numbers indicate:

- Track number (XXXX) where XXXX ranges from 0200 through 7776 (octal).

- Determination time (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

- If TN AMPLFY function is active, YYYY represents a four-digit (octal) data link track number.

- If the non sub symbol has a superimposed K, the contact is data link received.

 X
YYYY

REMOTE WEAPON SPLASH POINT

Remote weapon splash point marks the calculated position of a data link received weapon splash point.

- Splash point type (X) where X equals:

  M - Mine
  B - Bomb or Torpedo
  S - Nuclear Weapon

- If TN AMPLFY function is active, YYYY represents a four-digit (octal) data link track number.

XXXX
YYYY

MAN-IN-WATER (LOCAL OR REMOTE) or
PU EMERGENCY BAILOUT

Man-in-water symbol marks the position of a man in the water or the position at which an emergency bailout from a PU occurred.

·PU number (XXXX) is displayed when the symbol is designated as an emergency bailout.

·Time of entry (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

·If TN AMPLFY function is active, YYYY represents a four-digit (octal) data link track number.

XXXX
YYYY

RETURN TO BASE (PU EMERGENCY)

The return to base symbol marks the position a local or remote PU made the determination to make an emergency return to base.

·XXXX represents PU number.

·Time of entry (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

·If TN AMPLFY is active, YYYY represents a four-digit (octal) data link track number.

EXXX
YYYY

BASIC CONTACT

The basic contact symbol is used to mark a contact gained by a sensor on the aircraft or transmitted to the aircraft over data link. The symbol consists of a letter representing the sensor which gained contact or the source of the contact. The letters are:

L - LOFAR
D - DIFAR
A - CASS, DICASS and RO
E - ESM
K - Remote (data link input)
H - HYFIX
P - PAC

The associated numbers indicate:

- Contact number (XXX) where XXX ranges from 001 through 143 (octal).

- Entry time (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

- If TN AMPLFY is active, YYYY represents a four-digit (octal) data link track number.

ESM CONTACT (TAC PLOT)

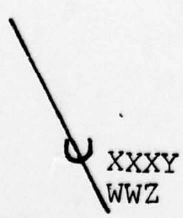
The ESM contact symbol is used to indicate an ESM bearing on the tactical plot. The symbol consists of a bearing line drawn from the aircraft position at the time of contact to the plot edge in the direction of the ESM contact. A basic contact (E) symbol is constructed one-inch from the bearing origin. The associated numbers indicate:

- Contact number (XXX) where XXX ranges from 001 through 143 (octal).

- Entry time (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

- If TN AMPLFY is active, YYYY represents a four-digit (octal) data link track number.

- K (instead of E) indicates a remote ESM contact.



ESM EMITTER (ESM PLOT)

ESM emitter symbol is used to indicate an ESM bearing with various classification data on the ESM plot. The symbol consits of a bearing vector similar to

the ESM contact symbol. The letters and numbers indicate:

- Classification (U) where U can be:

  U - Unknown
  F - Friendly
  H - Hostile

- Contact number (XXX) where XXX ranges from 001 through 143 (octal).

- Contact status (Y) where Y can be:

  E - Entered
  S - Special Threat

- Country of origin (WW) where WW designates the country of origin: (GE) German, (RU) Russian, (US) United States, (UK) United Kingdom, (FR) France, (CN) Canadian, (NE) Netherlands, (IT) Italy, (JA) Japan, (SW) Sweden.

- Platform designator (Z) where Z can be:

  S - Surface Vessel
  B - Submarine
  A - Aircraft

P XXXX
YYY

CONTINUOUS PREDICT

The Continuous Predict Position (CPP) symbol is used to mark the predicted contact position on the tac plot. The symbol position moves to coincide with the computer estimated contact position. It consists of the letter P with a ¼-inch vector extending in the direction of the predicted contact course. The associated numbers indicate:

- Track number (XXXX) where XXXX ranges from 0200 through 7776 (octal).

- Contact speed (YYY) where YYY ranges from 000 through 999 (visible in amplify).

- A remote CPP symbol is identified with the letters PK.

S XXXX
YYYY

SINGLE PREDICT

The single predict symbol is used to mark a computed contact position for a time designated by the operator. The symbol does not move after it is displayed. The designated time can be in the future or in the past. The symbol consists of the letter S. The associated numbers indicate:

- Track number (XXXX) where XXXX ranges from 0200 through 7776 (octal).

- Designated contact position time (YYYY) where YYYY ranges from 0000 through 2359 when amplified.

ZZZZZZZZZZ
☒ VVVV
YYYY

BASIC FIX

The basic fix symbol is used to mark contact fixes and tracks on the tac plot. The symbol consists of a classification identification symbol (see Figure 1-26) and a ¼-inch vector indicating the fix movement direction, if known. The associated letter and numbers indicate:

- Sensor source designator (X) where X can be:

A - CASS, DICASS, RO
E - ESM computed intersection
F - FLIR
H - HYFIX
K - Remote (data link input)
M - MAD
R - Radar
T - TACCO FIX DESIG
V - Visual
D - DIFAR or PAC computed intersection
(Blank) - Computed intersection with dissimilar sources

- Track number (VVVV) where VVVV ranges from 0200 through 7776 (octal).

- Fix time (YYYY) where YYYY ranges from 0000 through 2359 (visible in amplify).

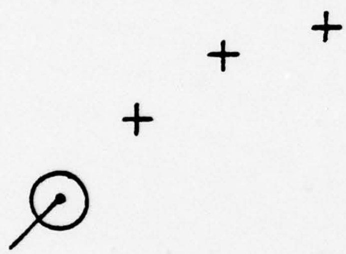
•If TN AMPLFY is active, YYYY represents a four-digit (octal) data link track number.

•Rigging (Zs) where up to 10 alphanumeric characters represent name, number or type that has been entered in the Rig tableau.

BASIC FIX SYMBOLOGY

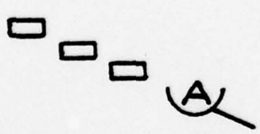
CLASSIFICATION	IDENTIFICATION		
	HOSTILE	FRIEND	UNKNOWN
SURFACE	◇	○	□
SUBSURFACE	V	◡	⊔
AIR	Λ	◠	⊓

AIRCRAFT OWN TRACK HISTORY



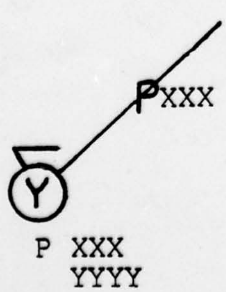
The aircraft own track history symbol marks the aircraft path history on the tac plot. It consists of up to 15 plus signs which appear at operator selected time intervals. When 15 signs are displayed, appearance of the next sign ages out the oldest sign in the track.

FIX HISTORY



The fix history symbol marks the track history of a subsurface, surface or airborne track and all fixes associated with a track which has been removed from the display by the GEN TRK function.

PAC CONTACT



The PAC contact symbol indicates a passive target acquisition on a single DIFAR or LOFAR buoy. The letter Y in the buoy symbol is D for DIFAR or L for LOFAR. Below the buoy symbol the letter P represents the hookable symbol. XXX is the contact number (0-377 octal). YYYY is acquisition time in amplify or

data link track number if TN AMPLFY function is active. A vector is displayed when the buoy is DIFAR and the PAC BRG function is active. The vector indicates a nonhookable symbol and the contact number.


AAB
CCCC

L XXX
YYYY

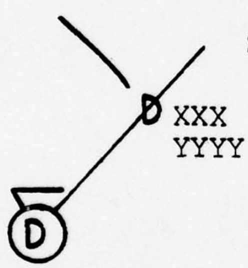
L XXX
YYYY

LOFAR CONTACT (SEPARATE TARGETS)

LOFAR contact symbols indicate separate target acquisitions on a single buoy. The symbol consists of the letter L with the associated contact number (XXX) and time the contact was entered on the tactical plot (YYYY). If a contact is destroyed (removed from memory) or cleared (removed from the display), the remaining symbols move up to fill the empty position.

Note

L does not reflect contact position.



SONOBUOY CONTACT BEARING

The sonobuoy contact bearing symbol group consists of the basic sonobuoy symbol with a D, S or K enclosed. A bearing vector extends from the buoy symbol in the direction of the contact out to the display area edge. A ¼-inch vector denotes the bearing change direction. The basic symbology, including contact number (XXX) and contact time (YYYY), is displayed one-inch from the buoy symbol when amplified.

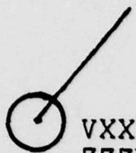
D = D - DIFAR
S - DICASS
K - Remote DIFAR contact

ACTIVE RANGE CONTACT

An active range contact symbol contains a basic sonobuoy with the basic contact symbol, a range circle centered on the buoy and corresponding to the active range. The circle size is updated at the Doppler rate and a ¼-inch vector denotes an opening or closing range direction. The basic symbology, including contact number (XXX)

and contact time (YYYY), is displayed when amplified.

Z = C - CASS
S - DICASS
R - RO



VXXX
ZZZM
or
ZZZZZY

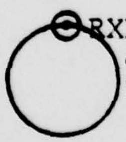
VECTOR

The vector symbol is controlled by the trackball and is used to measure a true bearing and distance on the MPD. The operator can originate the vector at the aircraft position symbol or from a hooked point. The symbol consists of a variable length vector extending from the aircraft symbol or a geographic position to the hook symbol. The letter V is displayed outside the hook symbol. The associated letters and numbers indicate:

·Vector direction relative to true north (XXX) where XXX ranges from 000 through 359.

·Vector length (ZZZM) if the plot scale is 32 NM or greater where ZZZ ranges from 000 through 999 (M indicates miles).

·Vector length (ZZZZZY) if the plot scale is 16 NM or less where ZZZZZ is indicated in yards (Y indicates yards).



RXXXM
or
ZZZZZY

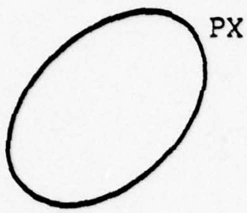
RANGE RADIUS CIRCLE

The range radius circle symbol is used to construct patterns on the tac plot. It consists of a circle centered on an operator designated geographic position with the circle radius controlled by moving the hook symbol. The range readout (XXXM or ZZZZZY) is preceded by the letter R. The range readout limits are the same as the vector symbol.

·Range readout (XXXM) is miles when plot scale is 32 NM or greater.

·Range readout (ZZZZZY) is in yards when plot scale is 16 NM or less.

PROBABILITY CONTOUR



The probability contour symbol is used to designate a geographic area within which the target will be found with an operator selected probability. The symbol consists of an ellipse representing the boundary of the probability area. The area size and shape depend on many conditions including the operator selected (desired) probability. The letter P followed by the selected probability X is presented at the northernmost point on the ellipse major (longest) axis. X ranges from .1 - .9.

LAT/LONG

LL XX XX XXN
XXX XX XXE

The lat/long symbol displays the latitude and longitude of a point.

- The first line contains the designator LL, a latitude readout in degrees, minutes, seconds; and a N/S direction indicator. The first character is hookable.

- The second line contains a longitude in degrees, minutes, seconds; and an E/W direction indicator.

- The third line contains a small circle which specifies the position for which the LL readout applies.

LAT/LONG (GRID COORDINATE REFERENCE)

LL YYY N NM
XXX E NM

The lat/long symbol displays the X and Y coordinates of a point with respect to the grid coordinate reference point.

- The first line contains the designator LL and a Y grid coordinate readout in nautical miles and a N/S direction indicator. The first character is hookable.

- The second line contains an X grid coordinate readout in nautical miles and an E/W direction indicator.

The third line contains a small circle which specifies the position for which the X and Y grid coordinates readout applies.

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